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BIOLOGICAL SCIENCES

MYCOBIOTA OF COTTON (GOSSYPIUM HIRSUTUM L.) CULTIVATED IN THE ARAN KARABAKH REGION (AZERBAIJAN): TAXONOMIC DIVERSITY AND ECOLOTROPHIC STRUCTURE

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Abstract

Cotton (Gossypium hirsutum L.) represents a key industrial crop cultivated in the semi-arid lowlands of Azerbaijan. The Aran Karabakh region is characterized by intensive irrigation agriculture, elevated summer temperatures, and periodically saline soils, all of which influence plant–microorganism interactions. The present study investigates the composition and ecological structure of microscopic fungi associated with cotton plants grown under field conditions in this region. Fungal isolates were recovered from roots, stems, leaves, and bolls using classical culture-based techniques followed by morphological identification. The obtained results demonstrated that the fungal assemblage was dominated by Ascomycetous taxa, particularly species of Fusarium, Alternaria, Aspergillus, Cladosporium, and Penicillium. Ecolotrophic assessment revealed a predominance of pathogenic and opportunistic saprotrophic forms, whereas endophytic representatives occurred less frequently. The findings contribute to understanding the fungal ecology of cotton agroecosystems in Azerbaijan and emphasize the necessity of phytosanitary surveillance in intensively cultivated arid landscapes.

Keywords: cotton; fungal diversity; agroecosystem; phytopathogens; Aran Karabakh; micromycetes

1. Introduction

Cotton is among the most economically valuable fiber crops worldwide and plays a strategic role in the agricultural sector of many semi-arid countries. Gossypium hirsutum L., the most widely cultivated species, accounts for the majority of global cotton production (FAO, 2023). In Azerbaijan, cotton cultivation is concentrated primarily in the lowland zones, including the Aran Karabakh territory, where irrigation compensates for limited precipitation.

Agroecosystems located in arid and semi-arid environments create favorable conditions for the development of diverse fungal communities. Soil temperature fluctuations, water stress, and anthropogenic agricultural practices significantly affect the composition of plant-associated microbiota (Compant et al., 2021). Cotton plants are particularly vulnerable to fungal infections that can impair root systems, vascular tissues, and reproductive organs.

Numerous studies report that Fusarium spp. are major causal agents of wilt diseases in cotton, leading to considerable yield reduction (Zhang et al., 2019; Wang et al., 2022). Alternaria and Cladosporium species frequently colonize aerial plant parts, while Aspergillus and Penicillium species are often isolated from seeds and stored plant material. Some of these fungi are capable of producing secondary metabolites with toxicological significance (Battilani et al., 2016).

Despite the recognized importance of cotton phytopathology globally, region-specific data concerning fungal communities associated with cotton in Azerbaijan remain insufficient. Therefore, this study aims to characterize the taxonomic composition and ecological-functional structure of fungi colonizing cotton plants cultivated in the Aran Karabakh lowland.

2. Materials and Methods

2.1 Study Area

The Aran Karabakh lowland is situated in the central part of Azerbaijan and represents one of the principal agricultural zones of the country. The region forms part of the Kura–Araz lowland and is characterized by flat to slightly undulating relief. It borders the foothill areas of the Lesser Caucasus and includes extensive irrigated agricultural lands where cotton cultivation is widely practiced.

The total area of the Aran economic region exceeds 21,000 square kilometers and plays a strategic role in Azerbaijan's agricultural production. Unlike mountainous territories, the landscape here is predominantly plain, with elevations generally ranging between 0 and 200 meters above sea level. The geomorphological structure consists mainly of alluvial and proluvial deposits formed by the Kura and Araz river systems. Sedimentary layers of Quaternary origin dominate the geological composition of the territory.

The climate of the Aran Karabakh region is semi-arid and dry subtropical. Summers are long, hot, and dry, with average July temperatures ranging between 25°C and 30°C, often exceeding these values during peak periods. Winters are relatively mild, with average January temperatures between 0°C and 5°C. Annual precipitation is limited, typically ranging from 250 to 350 mm, which makes irrigation essential for sustainable crop production.

Soils in the region are predominantly grey-brown (sierozem) and alluvial-meadow types. In certain areas, moderate soil salinity is observed due to intensive irrigation and high evaporation rates. The presence of carbonate-rich and clayey substrates influences water retention capacity and microbial activity in the soil profile. These edaphic conditions significantly affect

the composition and distribution of fungal communities associated with cultivated crops.

The hydrographic network is represented primarily by irrigation canals connected to the Kura and Araz rivers. Artificial reservoirs and drainage systems play a critical role in maintaining agricultural productivity. Continuous irrigation, combined with high summer temperatures, creates favorable microenvironmental conditions for the development and persistence of soil-borne and aerial fungal species in cotton agroecosystems.

2.2 Plant Material

Three cotton (Gossypium hirsutum L.) fields widely cultivated in the Aran region were selected as study sites. Plant samples were collected from tree natural fields during the vegetative growth stage. Healthy and visibly stressed cotton leaves, stems, and bolls were sampled to assess fungal diversity under different physiological conditions.***2.3 Fungal Isolation and Identification***

Fungal isolation was conducted using conventional mycological methods. Healthy and stressed leaves, stems, and bolls of cotton were aseptically placed on YGC (Yeast Extract-Glucose-Chloramphenicol) and DG18 (Dichloran-Glycerol) agar media and incubated at 25–27 °C. Colony development was monitored daily, and pure cultures were obtained through subculturing.

Identification of fungal isolates was based on macroscopic characteristics (colony shape, color, growth rate) and microscopic structures (conidia, hyphae, sporulation structures) using light microscopy. Taxonomic determination was carried out according to international mycological keys and reference databases.

During fungal cultivation in the laboratory, various equipment and materials were used, including autoclaves, magnetic stirrers, sterile flasks or Pyrex bottles, Petri dishes, and precise weighing scales. The choice of nutrient medium depends on the optimal growth conditions for each fungal species. Ready-made YGC and DG18 agar media were used for cultivation.

To prepare the nutrient media, 22.5 g of agar was accurately weighed per 1 L of distilled water, thoroughly mixed on a magnetic stirrer, and sterilized by autoclaving. Sterile media were poured into Petri dishes under UV-sterile conditions. Samples were handled aseptically with tweezers and placed into the dishes. Control plates were included to monitor any external contamination.

The plates were incubated at 25–27 °C, and full fungal development was usually observed within five days. The incubator temperature was measured and recorded daily to ensure stable growth conditions. Fungal development was monitored starting from the third day, and developed colonies were transferred to a clean environment for species identification.

Colonies were examined on slides using Gram staining under a microscope to determine species identity. For reference, databases of the International Association of Mycology and the CBC collection were used.

It is possible to determine whether the growth and development of mushroom species differ by the Growth Factor. The Growth Factor is based on a special formula: D is the diameter of the colony (measured in millimeters), H is the vertical size (height) of the colony, S is the density indicator of the colony (evaluated on a scale from 1 to 5), and T is the cultivation period (in days).

The systematic classification of plant species and their distribution frequency was calculated using the following method:

$$N = n / s$$

where **N** represents the frequency of occurrence (units per hectare), **n** is the number of individuals of a specific medicinal plant species observed in a given area, and **S** is the total area studied (in hectares).

The occurrence frequency of fungal species in the samples and the prevalence of diseases caused by pathogenic microorganisms were determined using the formula:

$$P = (n / N) \times 100$$

where **P** is the detection frequency of fungal species in the samples or the prevalence of pathogen-induced diseases (in %), **n** is the number of specific fungal samples (i.e., plants exhibiting disease symptoms), and **N** is the total number of plant samples examined.

All experiments were repeated at least three times, and the resulting data were analyzed using statistical methods. Only results meeting the following criterion were considered reliable and included in the dissertation:

$$m/M = P \leq 0.05$$

where **M** is the mean value, **m** is the standard deviation, and **P** is the probability level estimated using Student's t-test

2.4 Statistical Analysis

The frequency of fungal occurrence and plant colonization was calculated using standard ecological indices. All experiments were conducted in triplicate, and statistical reliability was assessed using Student's *t*-test, with significance accepted at $P \leq 0.05$.

3. Results

A total of more than 18 species of microscopic fungi were isolated from cotton plants. The majority of identified taxa belonged to the phylum Ascomycota (approximately 70%), while representatives of Mucorales (Zygomycota) accounted for about 30%.

The most frequently detected genera were Fusarium, Alternaria, Aspergillus, Penicillium, and Cladosporium. Fusarium species were predominantly isolated from root and stem tissues and were associated with vascular discoloration and wilting symptoms. Alternaria and Cladosporium were mainly detected on leaf surfaces, particularly in senescent tissues.

Saprotrophic fungi were commonly isolated from damaged bolls and post-harvest residues, whereas pathogenic species were more frequent in stressed plants exposed to high temperature and water deficit conditions.

4. Discussion

The predominance of Ascomycota corresponds with global observations of cotton-associated fungal communities (Zhang et al., 2019). Fusarium species are

widely recognized as destructive soil-borne pathogens capable of surviving in crop residues and soil for extended periods.

High summer temperatures and irrigation-dependent agriculture in the Aran Karabakh region likely promote fungal persistence and dispersal. Similar ecological patterns have been described in semi-arid cotton-growing systems (Wang et al., 2022).

Saprotrophic fungi contribute to organic matter decomposition within agroecosystems, whereas pathogenic forms pose direct risks to plant productivity. The relatively lower presence of endophytes may reflect environmental stress factors limiting mutualistic associations.

Overall, the fungal community structure appears to be shaped by climatic stress, soil properties, and intensive cultivation practices.

5. Conclusions

Cotton plants cultivated in the Aran Karabakh region host a diverse and ecologically heterogeneous mycobiota dominated by Ascomycetous fungi. Pathogenic species, particularly Fusarium and Alternaria, prevail in stressed plant tissues, while saprotrophic fungi colonize damaged and senescent organs.

The obtained results emphasize the importance of continuous phytopathological monitoring and integrated disease management strategies in cotton agroecosystems. Regular mycological control may contribute to improved yield stability, fiber quality, and environmental safety in the region.

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MYCOBİOTA OF ORCHARDS CULTİVATED İN AZERBAİJAN AND THE İMPACT OF THESE FUNGİ ON PHYSİOLOGİCAL PROCESSES İN PLANTS

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Abstract

In the conducted studies, a number of fruits distributed in the Greater Caucasus part of Azerbaijan were analyzed according to fungal microbiota. The majority of recorded fungi, more precisely 96.3%, belong to true fungi (Mycota or Fungi), and 3.7% belong to fungus-like organisms (Chromista). Most of the recorded true fungi, more precisely 67.0% (64.4% of total fungi) belong to Ascomycota, 26.0% (25.0%) to Basidiomycota, 6.8 % (6.5%) belongs to zygomycetes (Mycormycota). Parasitic fungi such as *Alternaria, Erysiphe, Puccinia, and Phytophthora* damage plant tissues by causing diseases such as powdery mildew, rust, and root rot, respectively, and cover the leaf surface by causing necrosis and spots on the leaves, destroying tissues, and thus reducing the photosynthetic capacity of the plant. Fungi of the genus *Fusarium and Phytophthora* damage plant roots, impairing water absorption by the roots, disrupting the water balance and causing wilting. Some fungi also disrupt the hormonal balance in plants by secreting hormones and toxins.

Keywords: mycobiota, plant physiology, phytopathogenic fungi, prevalence rate, physiological processes

Introduction. The territory of the Republic of Azerbaijan consists of ecosystems of different nature, and each ecosystem carries specific characteristics along with the general signs of the nature of Azerbaijan. It should be noted that, 8 of the 11 climate types are found in the not so large territory of the Republic of Azerbaijan. Such diversity has also influenced the flora of Azerbaijan and in the studies carried out so far, the distribution of about 5000 plant species has been determined in the territory of the Republic of Azerbaijan. The recorded plants are characterized by a wide diversity according to their taxonomic structure, life forms, purposes, resources, areas of use and other features [3].

It's no secret that plant-based products are an indispensable component of people's diet. Therefore, in the studies conducted in terms of providing the population with fruits, fresh vegetables and melon products, plant varieties with high productivity have been created, and currently they are widely used in the purchase of targeted products. Nevertheless, a certain part of the products obtained every year is lost due to various reasons, among the main reasons for this, diseases caused by various living things occupy an important place. It is no coincidence that today there are extensive researches on its prevention all over the world, and today this issue is one of the tasks that cannot be solved within any specific country. Thus, the role of the border factor in the spread of diseases caused by microorganisms is not so great. sing microorganisms in various groups of plants are also being studied.

Among these types of diseases, those caused by fungi are of particular importance, at least because the loss of yield during the epiphytoty of a disease caused by this or that fungi is sufficient, and sometimes even results in this product being completely useless. In general, it is estimated that at least 10% of the world's crop production is lost due to fungal diseases, which is expressed in millions of tons. In addition to these negative effects that manifest against the background of various diseases, fungi also have properties that stimulate physiological processes in the plant body and have a positive effect on plant development. Therefore, the purpose of the presented work is to study the species composition of the mycobiota of fruits cultivated in Azerbaijani conditions and to investigate the changes occurring in the physiological processes of these fungi in the plant organism.

Material and methods. Research has been conducted since 2021 in various economic regions of the Republic of Azerbaijan. For this purpose, samples were taken from the vegetative and generative organs of fruit plants cultivated in the mentioned areas and were analyzed according to the set goal. In taking samples, were used methods of selecting permanent areas for planned route and stationary observations, which are widely used in the course of mycological research [5]. In total, more than 1050 samples were taken and analyzed during the research. For the taking fungi to the pure culture were used standard nutrient mediums - Suslo agar, Saburo agar, Potato agar and agarized Chapek medium. The media were prepared, sterilized and poured into Petri dishes according to known methods [5]. A sample suspected of having a fungi is transferred to a nutrient medium and placed in a thermostat (260 ^{0}C) for a certain period of time (up to 10 days) until a colony is formed. After a colony or clump of mycelium is formed, it is re-inoculated into a clean medium for visual purity, and this process is continued until a pure culture is obtained. The purity of the culture is monitored with the help of a microscope. During the whole process, the day of colony formation, shape, color, color of the back side, smell, shape of mycelia, formation of conidia and other derivatives and changes in their shapes, sizes, etc. are recorded, and identification of mushrooms is carried out based on the determinants [8,12,13] drawn up on the basis of cultural morphological and physiological characteristics. The impact of fungi on physiological processes in plants was determined by clarifying observations made in studies and literature data.

Results and discussion. From the result of the analysis of samples taken from fruit plants cultivated in different areas of Azerbaijan, became clear that the number of fungi distributed in the studied plants is equal to 216. The majority of recorded fungi, more precisely 96.3%, belong to true fungi (Mycota or Fungi), and a small number (3.7%) belong to fungus-like organisms (Chromista). Most of the recorded true fungi, more precisely 67.0% (64.4% of total fungi) belong to Ascomycota, 26.0% (25.0%) to Basidiomycota, 6.8 % (6.5%) belongs to zygomycetes (Mycormycota). Among the recorded fungi, a number of genera participate in the formation of the mycobiota of the studied cultivated plants with a number of 10 or more species, here includs genera *Alternaria, Aschochyta, Aspergillus, Colletotrichum, Fusarium, Pencillium, Rhizopus, Septoria, Trichoderma, Verticillium.*

The fungi recorded in the studies differed from each other in terms of their ecotrophic relationship to the fruits studied. Thus, among the recorded fungi, both true biotrophs (*A. alternata, A. mellea, Asc. fagi, A. niger, A. versicolor, Botrytis cinerea, E. communis, E. deformans, E. amygdale, F. fomentarius, G. confusum, T. discolor, T. pruni-spinosae and U. salviae*) and polytrophs (*C. puteana, F. annosa, F. cyticinia, F. pinicola, G. lipinse, Ph. igniarus, P. ostreatus, Sch. commune, T. hirsuta and T. versicolor*), that is, those that do not have a true saprotrophic and biotrophic nature, were found. These fungi are mainly universal in terms of the nature of the pathology they cause in the studied plants, since the pathologies of the same name they cause are recorded in several or all of the plants.

The fungi recorded during the research caused various pathologies in plants. Species belonging to the genera *Alternaria, Ascochyta, Botrytis, Fusarium, Phoma, Puccina, Septoria, Urocystis, Uromyces, Verticellium*, etc. caused mold, rust, wilting, black and brown spots, rot, powdery mildew, etc. in plants, causing serious changes in both their morphological and biochemical indicators. Many of the mentioned fungi have the ability to synthesize biologically active substances such as phytohormones or mycotoxins as secondary metabolites as a result of their life activities.

Fungi can affect physiological processes in plants in a variety of ways. These effects include both negative effects that weaken plant health and positive effects that support growth and development. Negative effects can manifest in the form of parasitism, mycotoxin secretion, infection, and spread. For example, parasitic fungi such as *Alternaria, Erysiphe, Puccinia, and Phytophthora* damage plant tissues by causing diseases such as powdery mildew, rust, and root rot, respectively, and cover the leaf surface by causing necrosis and spots on the leaves, destroying tissues, and thus reducing the photosynthetic capacity of the plant. At the same time, it limits the supply of oxygen to the plant and weakens energy production. Fungi of the genus *Fusarium and Phytophthora* damage plant roots, impairing water absorption by the roots, disrupting the water balance and causing wilting. Some fungi also disrupt the hormonal balance in plants by secreting hormones and toxins. The hormone gibberellin, produced by the fungus *Gibberella*, causes abnormal growth of plant tissues. Toxins produced by fungi of the *Alternaria* genus increase the amount of abscisic acid, leading to premature leaf drop. Aspergillus species secrete a variety of mycotoxins, including aflatoxins, ochratoxins, and sterigmatocystin, which cause oxidative stress in leaves, damaging the structure of chloroplasts, and inhibiting electron transfer in Photosystem II (PSII), which reduces the conversion of light energy to chemical energy. This process is observed by the oxidation and inactivation of proteins, especially in PSII. Aspergillus toxins direct plant resources to defense mechanisms. This reduces the energy and nutrients available for photosynthesis and other metabolic processes.

The positive effects of fungi on plant organisms have also been widely studied. Mycorrhizal and symbiotic fungi stimulate the absorption of nitrogen, phosphorus, water, and other minerals in the soil by plant roots. Beneficial fungi stimulate the production of plant hormones (auxin, cytokinin), which accelerate the growth of roots and shoots. They also decompose dead plant and animal remains, enriching the soil with nutrients that can be absorbed by plants. Fungi also participate in the fight against harmful microorganisms. For example, fungi of the genus *Trichoderma* protect plant roots from harmful bacteria. Fungi such as *Trichoderma* make plants more resistant to biotic and abiotic stresses. They protect plant cells from harmful effects by activating antioxidant defense mechanisms.

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GEOBOTANICAL STUDY OF PIRSHAĞI LAKE AND SURROUNDING AREAS: ECOSYSTEM CHARACTERISTICS AND SUSTAINABLE MANAGEMENT PROPOSALS

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Abstract

This study examines the geobotanical characteristics and ecosystem functions of Pirshağı Lake and its surrounding areas, located in the southern part of Azerbaijan's Absheron Peninsula. The research focuses on the Tamarixeta-Artemisietum-Alhagiosum plant formation, which plays a crucial role in the local ecosystem. The surrounding vegetation is vital for water regulation, soil conservation, and maintaining ecological balance. The impact of anthropogenic activities on vegetation productivity is also assessed, with strategies for sustainable land management proposed. The study is based on field surveys conducted in 2025 and offers recommendations for future land management practices.

Keywords: Pirshağı Lake, wetland vegetation, ecosystem functions, productivity, sustainable management, environmental conservation.

Introduction

Pirshağı Lake, located on the southern part of the Absheron Peninsula in Azerbaijan, is an ecologically important area, characterized by diverse plant life, particularly wetland vegetation. The surrounding vegetation plays a key role in maintaining the balance of the local ecosystem, with the Tamarixeta-Artemisietum-Alhagiosum plant formation being a major contributor. This plant formation supports biodiversity and significantly contributes to water regulation and soil conservation.

However, anthropogenic factors, such as industrialization and overgrazing, are exerting pressure on these ecosystems. This study aims to examine the bioecological characteristics of the wetland vegetation around Pirshağı Lake and propose sustainable management strategies for the protection and restoration of the area.

Research Objectives

1. To analyze the species composition and structure of the vegetation around Pirshağı Lake, focusing on the Tamarixeta-Artemisietum-Alhagiosum formation.
2. To assess the productivity of these vegetation types and their role in maintaining the ecosystem.
3. To evaluate the impact of human activities and natural processes on land productivity and ecological health.
4. To propose sustainable management practices aimed at improving and restoring these ecosystems.

Vegetation of Pirshağı Lake and Surroundings

The dominant vegetation around Pirshağı Lake consists of scrub-grass formations, notably the Tamarixeta-Artemisietum-Alhagiosum plant formation. This vegetation is crucial for maintaining local biodiversity and ecological stability. Field surveys conducted in 2025 provided the following productivity data for the area:

Table 1:

Productivity of Vegetation around Pirshağı Lake (2025)

Botanical Groups	Dry Biomass (kg/ha)	Percentage (%)
Gramineae (Grasses)	1.7	20
Leguminosae (Legumes)	4.2	49.4
Miscellaneous Herbs	2.6	30.6
Average Productivity	**8.5**	**100**

The results show that legumes, particularly *Alhagi pseudoalhagi*, contribute the most to biomass production, followed by miscellaneous herbs and grasses. The overall productivity of the vegetation in this region is moderate, with legumes playing a critical role in sustaining biomass levels.

Impact of Anthropogenic and Technogenic Activities

The study highlights the negative effects of human activities on the productivity of Pirshağı Lake and the surrounding land. Overgrazing, soil erosion, and industrial pollution have led to land degradation, adversely affecting vegetation health and productivity.

To mitigate these impacts, the study suggests that sustainable land management practices be implemented. Specifically, rotational grazing, land restoration, and soil fertilization are recommended to improve the productivity of the area and restore ecological balance.

Sustainable Management Strategies

Based on the study's findings, the following sustainable management practices are proposed for Pirshağı Lake and its surrounding areas:

1. **Rotational Grazing**: This practice would help reduce overgrazing pressure on the vegetation, allowing for natural regeneration of soil and plant communities.

2. **Land Restoration and Enhancement**: Introducing appropriate forage plants and utilizing bioengineering techniques can aid in the restoration of degraded areas and enhance soil fertility.

3. **Use of Organic and Mineral Fertilizers**: Fertilizing the soil can help restore fertility, promote plant growth, and improve overall productivity.

4. **Conservation of Endemic Species**: Protecting endemic species, such as *Tamarix ramosissima* and *Alhagi pseudoalhagi*, is essential for maintaining biodiversity and ecological stability in the region.

Conclusion

Pirshağı Lake and its surrounding wetland vegetation are vital to the ecological balance of the region. The productivity of the vegetation is moderate, with legumes making the greatest contribution to biomass production. However, anthropogenic activities, including overgrazing and industrial pollution, have negatively affected the land's productivity and health.

This study underscores the importance of sustainable land management practices, including rotational grazing, land restoration, and soil fertilization, to improve ecological health and productivity. The proposed strategies aim to restore and preserve the region's ecological functions, ensuring the long-term sustainability of Pirshağı Lake and its surrounding areas.

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PLANT BIOMASS DYNAMICS IN MOUNTAIN CHESTNUT SOILS OF THE AGHDARA REGION (AZERBAIJAN)

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Abstract

This study examines the structure of vegetation and the relative distribution of plant biomass in natural and cultivated cenoses developed on dark mountain chestnut soils of the Aghdara region (Azerbaijan). Field observations were conducted in two contrasting ecosystems: natural steppe vegetation and an agricultural forage community. The analysis focused on the dominant plant groups and their contribution to the formation of above-ground biomass. Results showed noticeable differences in the proportion of fresh and dry biomass between natural and cultivated environments. Natural plant communities demonstrated a more stable vegetation structure and a higher share of structurally persistent biomass. The findings highlight the important role of vegetation cover in maintaining soil organic matter and ecosystem stability.

Keywords: plant biomass; mountain chestnut soils; natural cenosis; agrocenosis.

Introduction. Mountain chestnut (grey-brown) soils are widely distributed in the dry subtropical landscapes of the South Caucasus. These soils are typical for foothill and steppe zones and occur in several regions of Azerbaijan, including the Greater and Lesser Caucasus, the Karabakh uplands, and Nakhchivan. They are characterized by relatively well-defined soil horizons, moderate aggregation, and a high carbonate content, which distinguishes them from other brown soil types. The formation of grey-brown soils is strongly influenced by climatic and ecological conditions typical for dry subtropical steppe ecosystems. The mean annual air temperature in these areas ranges from approximately 10.5 to 14.2 °C, while annual precipitation varies between 275 and 440 mm. Such conditions lead to moderate soil moisture levels, with a humidity coefficient generally ranging from 0.30 to 0.50. Winters are relatively mild and summers are hot, which strongly influences vegetation structure and productivity [1, 2, 3, 4, 5, 6].

Vegetation plays a fundamental role in soil formation processes in these ecosystems. Natural herbaceous communities contribute organic matter that later undergoes biochemical transformation and humification, forming the humus horizon of soils. The amount and composition of plant biomass therefore represent important indicators of ecosystem functioning and soil fertility [7, 8, 9, 10, 11, 12].

Mountain chestnut soils are commonly divided into several subtypes depending on morphological characteristics and environmental conditions. Among them are dark mountain chestnut soils, typical mountain chestnut soils, light mountain chestnut soils, and carbonate-rich variants. These soils often support natural steppe vegetation or are used for agricultural purposes such as orchards and forage crops[13, 14, 15, 16, 17, 18].

The present study focuses on dark mountain chestnut soils in the Aghdara region of Azerbaijan. The main aim of the research was to evaluate plant biomass formation in both natural plant communities and cultivated agrocenoses and to analyze the relationship between plant biomass and soil humus content.

Materials and Methods. The research was conducted in the Aghdara district, where dark mountain chestnut soils are widely distributed in foothill areas, particularly in the direction of the Talish settlement. These soils develop under natural steppe vegetation and are often used for agricultural production.

Two different types of biotopes were selected for the study: Natural cenosis (undisturbed steppe vegetation) and Cultivated agrocenosis (irrigated alfalfa field) The comparison between these two ecosystems allowed the assessment of how natural vegetation and agricultural management affect plant biomass accumulation[19, 20, 21, 22].

The measurement of above-ground plant biomass was carried out using a methodology adapted from the classical approach proposed by Bystritskaya and Osichnyuk. Two types of measurements were performed: fresh biomass weight and air-dried biomass weight[23, 24, 25].

After drying, the biomass data were recalculated to represent biomass per square meter (g/m²). Before measuring biomass in the natural cenosis, the species composition of wild plants was determined through herbarium analysis. This procedure allowed the identification of dominant plant families and genera involved in the formation of vegetation cover on dark mountain chestnut soils. The obtained data were then compared with published literature values for different subtypes of mountain chestnut soils in order to assess the ecological productivity of the studied ecosystems [26, 27, 28, 29].

Results and Discussion. Floristic analysis revealed that the plant biomass in the natural biotope was primarily formed by species belonging to three main botanical families: *Asteraceae (Compositae), Poaceae (Gramineae), Capparaceae.*

Within these families, several characteristic genera were identified. Representatives of the genus *Artemisia* (wormwood) were dominant among the *Asteraceae*. Grasses included genera such as *Festuca, Stipa,* and *Anthropogon*, while *Capparis* species represented the *Capparaceae* family. These plant groups form the

typical vegetation structure of steppe ecosystems developed on dark mountain chestnut soils. The presence of wormwood-grass associations indicates adaptation to arid climatic conditions and carbonate-rich substrates.

The vegetation formations observed in the study area can be broadly classified into two main ecological groups: Wormwood-ephemeral-grass formations and Grass-dominated steppe communities.

Such plant associations are characteristic for dry subtropical steppe environments and play an important role in stabilizing soil surfaces and contributing organic matter to the soil.

According to published studies, the above-ground biomass of mountain chestnut soils varies depending on the subtype. Typical values reported in the literature are:

- Dark mountain chestnut soils: ~540 g/m²
- Typical mountain chestnut soils: ~460 g/m²
- Light mountain chestnut soils: ~440 g/m²

In irrigated agricultural ecosystems, biomass production can increase significantly, reaching values between 700 and 1000 g/m².

These differences demonstrate the strong influence of water availability and vegetation type on biological productivity.

In the present study, the measured above-ground biomass values were as follows:

Natural cenosis (undisturbed vegetation): fresh biomass (613 g/m²); dry biomass (357 g/m²). Cultivated agrocenosis: fresh biomass (667 g/m²) ; dry biomass (292 g/m²).

The results indicate that fresh biomass in the cultivated agrocenosis was slightly higher than in the natural vegetation. However, the dry biomass values were lower in the agrocenosis. This difference can be explained by the higher moisture content in the cultivated plants, particularly in alfalfa, which is known for its succulent tissues and intensive growth under irrigation.

Plant biomass plays a key functional role in terrestrial ecosystems. The organic matter produced by plants undergoes decomposition processes involving microorganisms, soil fauna, and enzymatic reactions. These processes result in the transformation of plant residues into humus and other stable organic compounds that enhance soil fertility.

Furthermore, plant biomass serves as an energy source for soil organisms and contributes to nutrient cycling within ecosystems. Through the activity of microorganisms and soil fauna, accumulated organic matter is gradually converted into mineral nutrients available for plant uptake.

One of the important findings of the study is the observed relationship between plant biomass and soil humus content. In the natural cenosis, where plant biomass reached 613 g/m², the humus content of the soil was approximately 3.1 %. In the cultivated agrocenosis, the increase in fresh biomass to 667 g/m² corresponded with a slightly higher humus content of about 3.4 %.

This relationship demonstrates that higher levels of plant productivity can contribute to greater accumulation of organic matter in soils. The continuous input of plant residues promotes humification processes and improves soil structure, nutrient availability, and biological activity.

Conclusion. The conducted research allowed the evaluation of vegetation structure and plant biomass formation in dark mountain chestnut soils of the Aghdara region.

The results showed that natural vegetation is mainly composed of species belonging to three dominant plant families: *Asteraceae, Poaceae, and Cappa-raceae.* These plants form characteristic steppe communities adapted to the dry subtropical climate of the region.

Comparative analysis of the two studied biotopes demonstrated differences in biomass accumulation between natural and cultivated ecosystems. Fresh plant biomass reached 613 g/m² in the natural cenosis and 667 g/m² in the irrigated agrocenosis, while dry biomass was 357 g/m² and 292 g/m², respectively.

The study also revealed a relationship between plant biomass and soil humus content, indicating that higher levels of vegetation productivity can contribute to increased humus formation.

Overall, the findings emphasize the ecological importance of plant biomass in soil formation processes and ecosystem functioning. Understanding these relationships is essential for sustainable land management and the conservation of soil fertility in steppe environments.

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CULTURAL SCIENCES

THE ROLE OF NAKCHIVAN INTELLECTUALS IN AZERBAIJAN-TURKEY LITERARY RELATIONS DURING THE PERIOD OF INDEPENDENCE

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Abstract
In this article, the role of Nakhchivan intellectuals in Azerbaijan-Turkey literary relations is determined. As we know, since the end of the 20th century, especially after Azerbaijan regained its independence, the relations between our countries have strengthened, and commendable work has been done in this field. Azerbaijan's mutual cooperation with the Republic of Turkey is a bright example of our country's new relations with foreign countries, the friendship and brotherly relations of a sovereign state with equal rights, and the expression of the new political-economic and national-ideological thinking established in international affairs. Scientists, writers and poets have a special role in the comprehensive development of these relations.

Keywords: Turkey-Azerbaijan relations, Nakhchivan intellectuals, national-spiritual wealth, poet, writer

The history of Azerbaijani-Turkish literary relations began in ancient centuries and continues to develop to this day, enriching both literatures with new creative qualities. These two states, which share a common language, religion, national customs and traditions, historical heroes, and personalities, are connected to each other with unbreakable threads. It is impossible to study the national uniqueness of “one nation, two states” - Azerbaijan and Turkey - in isolation from each other. Despite the seventy-year strict prohibitions and political prohibitions of the Soviet empire, literary relations between Azerbaijan and Turkey have always continued. The changes and new approaches that occurred in socio-political life in the 90s did not bypass literature and literary relations. Over the years, as time changed, the public view of various issues also changed. It became necessary to reconsider a number of issues that were assessed objectively in the post-Soviet space and evaluate them from the point of view of national values. A number of articles and several poetry books have been published in this vein by the poet Khanali Karimli, PhD in Philology, Associate Professor, who has contributed to the development of Azerbaijani-Turkish literary relations. The author has published more than 10 articles on Azerbaijani-Turkish literary relations, both in the country and abroad. Khanali Karimli's book "Ahlat daşı" was published by the "Sam Yayınları" publishing house in Istanbul. Most of the poems in the book are dedicated to the poet's Turkish-Azerbaijani literary relations and the eternal friendship of these peoples. The monograph "Nakhchivan literary environment in the East-West context" presented to the scientific community by the young researcher Nargiz Ismayilova, who is the author of many scientific, artistic and translation works, is a serious scientific research work. The monograph was published by "Akademisiyen kitab evi" in the Republic of Turkey. The author of the preface, academician Isa Habibbeyli, who talks about the content and significance of the monograph, writes: "In the monograph, the East-West traditions in the Nakhchivan literary environment, which began in ancient and medieval times and further developed in the 19th-20th centuries, are extensively studied and generalized. The author theoretically explained and substantiated with artistic examples that the traditions of Eastern literature developed widely in the classical period of the Nakhchivan literary environment" (Habibbeyli I., 2020)

Examples of literary creativity of famous writers living in Nakhchivan, such as Khanali Karimli, Asim Yadigar, Ibrahim Yusifoglu, Elkhan Yurdoglu, Gafar Garib and others, have been published in various publishing houses in Turkey.

Since it is impossible to list all the examples of publications in one article, I would like to draw attention to one issue: the special role of well-known scientists, writers and poets in Turkish-Azerbaijani literary relations, which is reflected in the books and works of various genres published in Turkey by prominent Azerbaijani writers. From this point of view, important tasks also fall on the scientists and writers living in Nakhchivan, which is an integral part of Azerbaijan.

In this sense, the publication of Nakhchivan literature, which has a special place in the Turkish world and the Turkish literary environment and is famous for its artists who have created pearls of art and words, will continue to be very successful in Turkey, and our relations will be further strengthened.

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EARTH SCIENCES

DEPOSITIONAL CONDITIONS AND PETROPHYSICAL CHARACTERISTICS OF THE PRODUCTIVE SERIES IN THE NEFT DASHLARY AREA

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Abstract

The study of the petrophysical characteristics of sedimentary deposits is an important tool for reconstructing depositional environments and paleogeographic settings. Parameters such as porosity, permeability, density, water and hydrocarbon saturation, as well as electrical and elastic properties reflect both primary sedimentary features and the influence of post-sedimentary processes. The analysis of these data makes it possible to distinguish lithofacies types, assess the spatial variability of reservoir and sealing strata, and improve the reliability of stratigraphic correlation.

The facies method used in paleogeographic analysis helps to identify hydrocarbon-bearing reservoir rocks and productive horizons, thereby refining patterns of rock distribution and depositional environments.

The aim of this article is to conduct a comprehensive analysis of the petrophysical and lithofacies characteristics of the Productive Seriesin the Neft Dashlary area in order to reconstruct depositional conditions and clarify the patterns of reservoir rock formation. The reconstruction was carried out based on the analysis of well-logging data using the Emery method and cyclostratigraphic analysis. The results show that hydrocarbon accumulations are associated with deposits of the Fasila Suite (FS), the Lower Kirmaky Suite (LK), and the Kirmaky Suite (KS) of the Productive Series. The study revealed that the formation and accumulation of hydrocarbons occurred during progradational, retrogradational, and aggradational stages.

The reservoir properties of deposits belonging to the Balakhany Suite horizons (VII, VIIa, and X) and the Fasila, Upper Kirmaky Clay (UKCa), Upper Kirmaky Sandy (UKS), Kirmaky (KS-2), Lower Kirmaky (LK-1, LK-2 upper, LK-2 lower), and Qala (QaS) Suites of the Productive Series were analyzed. In addition, regression analysis was performed to determine the correlation relationships between the main petrophysical parameters of these deposits.

Keywords: well log section, facies, suite, reservoir rock, depositional environments, Productive Series.

INTRODUCTION

A comprehensive study of oil and gas fields, including cyclic and lithofacies analyses, as well as the investigation of petrophysical characteristics, is a key tool for reconstructing the depositional conditions of sedimentary strata and assessing hydrocarbon potential [5]. The application of these methods enables not only the determination of paleo-geological conditions of rock formation, but also the use of the results to improve the efficiency of hydrocarbon exploration and prospecting.

Lithofacies analysis is the first stage of formation analysis and is aimed at identifying the conditions of rock formation based on diagnostic features. Lithofacies studies play a particularly important role in hydrocarbon exploration, especially where hydrocarbons accumulate in various types of traps (lithological, stratigraphic, etc.). These methods facilitate stratigraphic correlation, forecasting, and the evaluation of cap rocks and reservoir rocks, and also allow the reconstruction of paleotectonic and paleogeographic settings [6].

Under conditions of limited core sampling, the effectiveness of traditional methods may be reduced, which necessitates the use of indirect approaches, in particular lithofacies interpretation of well-logging data.

Thus, at present, the study of depositional environments is considered a crucial component of exploration activities in oil and gas fields, aimed at identifying not only anticline structures but also non-anticlinal traps. The information obtained about rock genesis makes it possible to predict zones of reservoir development and clay sealing units.

MATERIALS AND METHODS

The present study aims to investigate the lithofacies and petrophysical characteristics of the Productive Series (PS) of the Neft Dashlary area, which allows the reconstruction of depositional conditions and clarifies the patterns of formation and distribution of reservoir rocks.

The Neft Dashlary field is located in the Caspian Sea, in the southeastern part of the Absheron Archipelago, east of Chilov Island, 110 km from Baku (Fig. 1).

The reservoirs of the Productive Series contain rich, multi-layered oil accumulations. From top to bottom, the Productive Series is subdivided into the following suites and horizons: the Surakhany (horizons Iı and I), the Sabunchi (II, III, IV), the Balakhany (V, VI, VII, VIII, IX, X), the Fasila, the Upper Kirmaky Clay (UKCa), the Upper Kirmaky Sandy (UKS), the Kirmaky (KS-U, KS-I, KS-2), the Lower Kirmaky (LK-1U, LK-1, LK-2 upper, LK-2 lower), and the Qala (QaS-1, QaS-2, QaS-3, QaS-4).

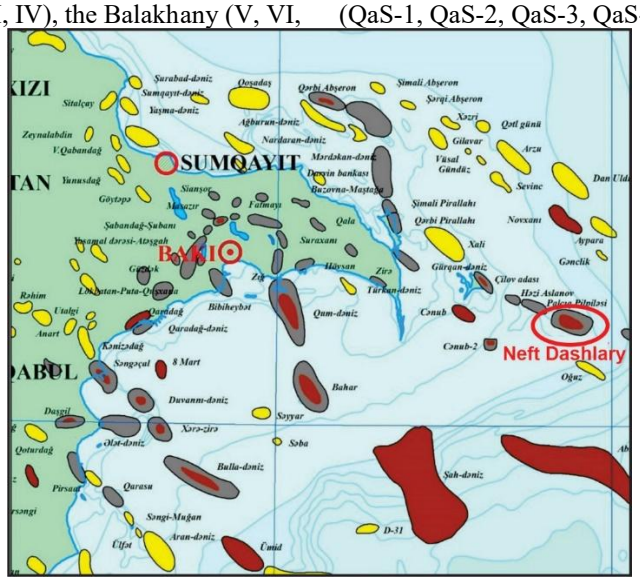


Fig. 1. Location map of the Neft Dashlary area

The geological section of the Neft Dashlary field comprises 26 oil-bearing horizons and reservoirs. The Productive Series is divided into upper (Surakhany, Sabunchi, Balakhany, and Fasila Suites) and lower (UKC, UKS, KS, LK, QaS) subdivisions.

The Neft Dashlary uplift is located in the pre-Absheron sector of the Absheron–Pribalkhan tectonic uplift belt and represents an independent anticlinal structure [4].

To investigate the structure of the sedimentary section, a set of geophysical well-logging methods was used, including gamma-ray (GR) logging and the spontaneous potential (SP) method. The logging data obtained from well No. 2690 of the Neft Dashlary oil and gas field were interpreted, allowing identification of changes in the lithological composition of the rocks [7, 8]. The reconstruction of depositional environments was performed based on the analysis of well logs using the Emery method [1, 2, 3]. The cyclicity of the section was analyzed using cyclostratigraphic methods based on the collected data. The study focused on the deposits of the Productive Series, namely the Balakhany Suite (VII, VIIa, X), as well as the Fasila Suite, the Upper Kirmaky Clay (UKC, UKCa), the Upper Kirmaky Sandy (UKS), the Kirmaky (KS, KS-2), Lower Kirmaky (LK-1, LK-2 upper, LK-2 lower), and Qala (QaS) Suites.

Subsequently, the reservoir properties of these suites and horizons were analyzed. Correlation between the main petrophysical parameters of these deposits was also examined.

RESULTS AND DISCUSSION

Within the framework of the study, reservoirs were identified and their properties determined, including porosity, permeability, and hydrocarbon saturation (Khc), as well as lithology and saturation characteristics of each reservoir. All these data were analyzed together with the results of interpretation using the Emery method and cyclostratigraphic analysis. The results of the analysis are presented below.

The Qala Suite (QaS) mainly consists of clay deposits and sandstones alternating with siltstones and fine-grained sands. The thickness of sandstones and siltstones reaches 20–25 m. The sands are composed of medium- and fine-grained quartz grains, while the clays contain minor sand and moderate carbonate content. Four oil and gas horizons have been identified within this suite. The sandy horizons are separated by clay layers, with thicknesses ranging from 10–25 m to 30–70 m. The lithological characteristics and thicknesses of the sandy horizons and the separating clay layers vary across the area. The sand fraction increases upward within the suite. Aggradation of clays is observed in the QaS (Fig. 2). The calculated average porosity (Kp) is 0.160, the permeability is 0.018, and Khc = 0.101.

The Lower Kirmaky (LK) Suite is composed of quartz sands and sandstones interbedded with medium- and coarse-grained sandy loams and clays, with clays comprising about 30% of the section in the lower and middle parts. The thickness of clay layers separating the sandy horizons ranges from 5–12 m to 20 m. The total thickness of the suite varies from 72 to 135 m, with an average of 110 m. The LK Suite includes the reservoirs LK-1, LK-2 upper, and LK-2 lower. Progradation, aggradation, and progradation–retrogradation are observed within these reservoirs (Fig. 2). Porosity (Kp) ranges from 0.193 to 0.229, permeability from 0.019 to 0.101, and hydrocarbon saturation (Khc) from 0.159 to 0.669.

The KS Suite consists of alternating sequences of fine-grained sands, sandstones, and clays. Downsection, the thickness of sandy layers increases up to 10 m, accompanied by coarsening of the grains. The clay interlayers separating sandy rocks range from 5–10 m thick. In well No. 2690, the KS Suite is represented by one reservoir, KS-2, in which progradation and aggradation are observed (Fig. 2). The thickness of the suite ranges from 165 to 350 m, with an average of 286 m.

The KS-2 reservoir is fully hydrocarbon-bearing, with an average porosity (Kp) of 0.156. Hydrocarbon saturation (Khc) ranges from 0.512 to 0.521, and permeability from 0.030 to 0.034.

The Upper Kirmaky Sandy (UKS) Suite consists predominantly of sandstones and, less commonly, medium- and coarse-grained clayey sands. Low-density sands are present, and sandstones occur in a compacted, well-cemented form. Gravel is also present within the suite. Aggradation is observed in the UKS Suite (Fig. 3). Calculations show that the average porosity (Kp) is 0.217, permeability ranges from 0.063 to 0.096, and hydrocarbon saturation (Khc) is 0.577.

The Upper Kirmaky Clay (UKCa) Suite is composed of a limited amount of sands and sandstones of varied grain size, as well as clays with interbeds of siltstones. In the upper part of the main layer, clays predominate. The sand fraction (up to 40%) is significantly higher than in adjacent deposits and increases upward within the suite. The lower part of the section, 25–40 m thick, consists of sandy deposits and contains oil in blocks II, III, IV, and V. The total thickness of the suite ranges

from 90 to 220 m, with an average thickness of 147 m. Retrogradation, aggradation, and

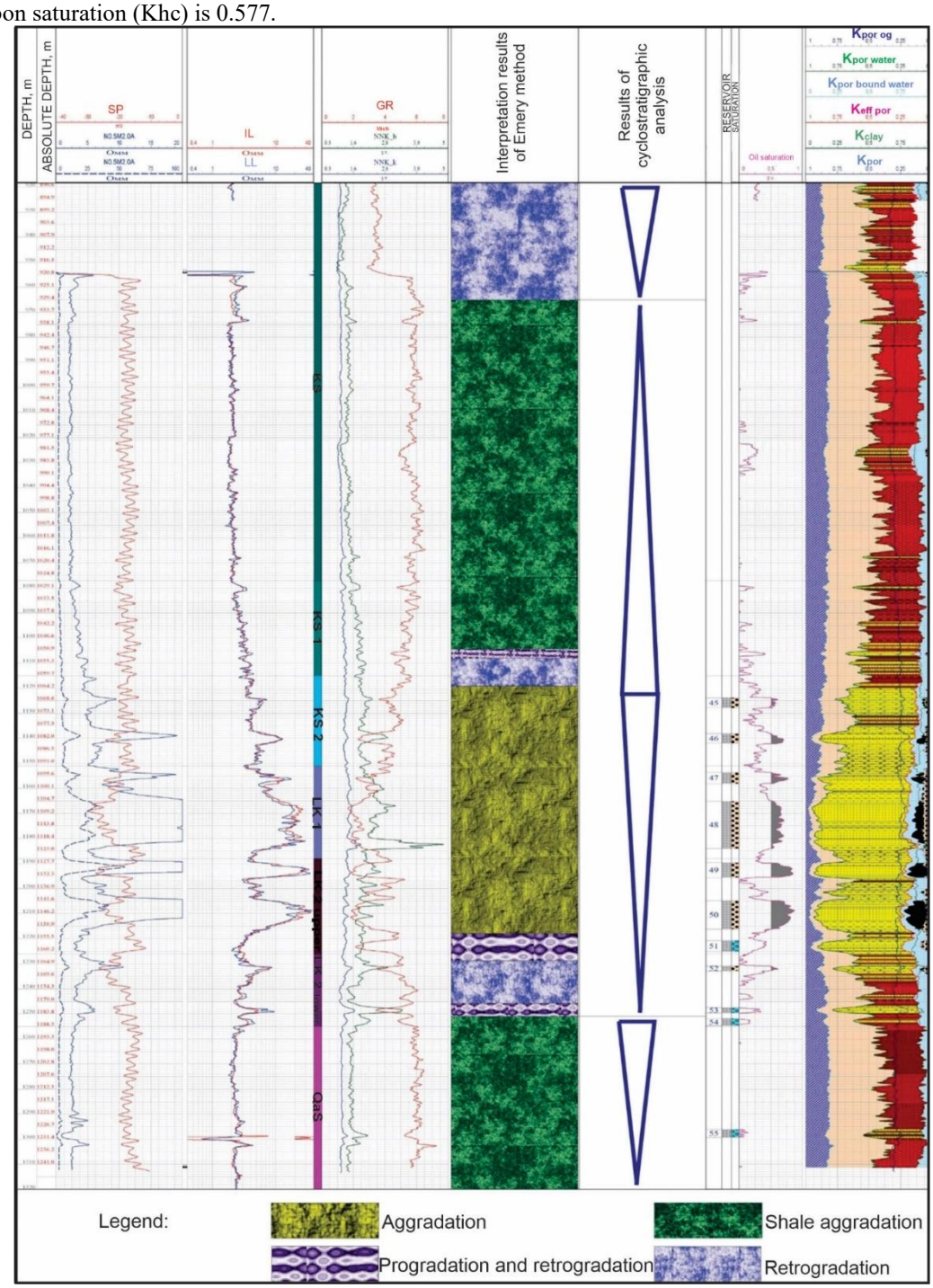


Fig. 2. Results of Emery and cyclostratigraphic interpretation of the Qala, Lower Kirmaky, and Kirmaky Suites in well Neft Dashlary No. 2690

progradation–retrogradation processes are observed in the UKC Suite (Fig. 3). Porosity (Kp) ranges from 0.154 to 0.161, permeability from 0.030 to 0.034, and hydrocarbon saturation (Khc) from 0.508 to 0.514.

The Fasila Suite is represented by poorly developed thin interbeds of clay, quartz sands (containing gravel), and sandstones. The thickness of the suite is 78 m. In well No. 2690, 11 reservoir layers are identified within the Fasila Suite, 3 of which are water-bearing and the remaining 8 oil-bearing. Aggradation is observed in the Fasila Suite (Fig. 3). Hydrocarbon saturation (Khc) ranges

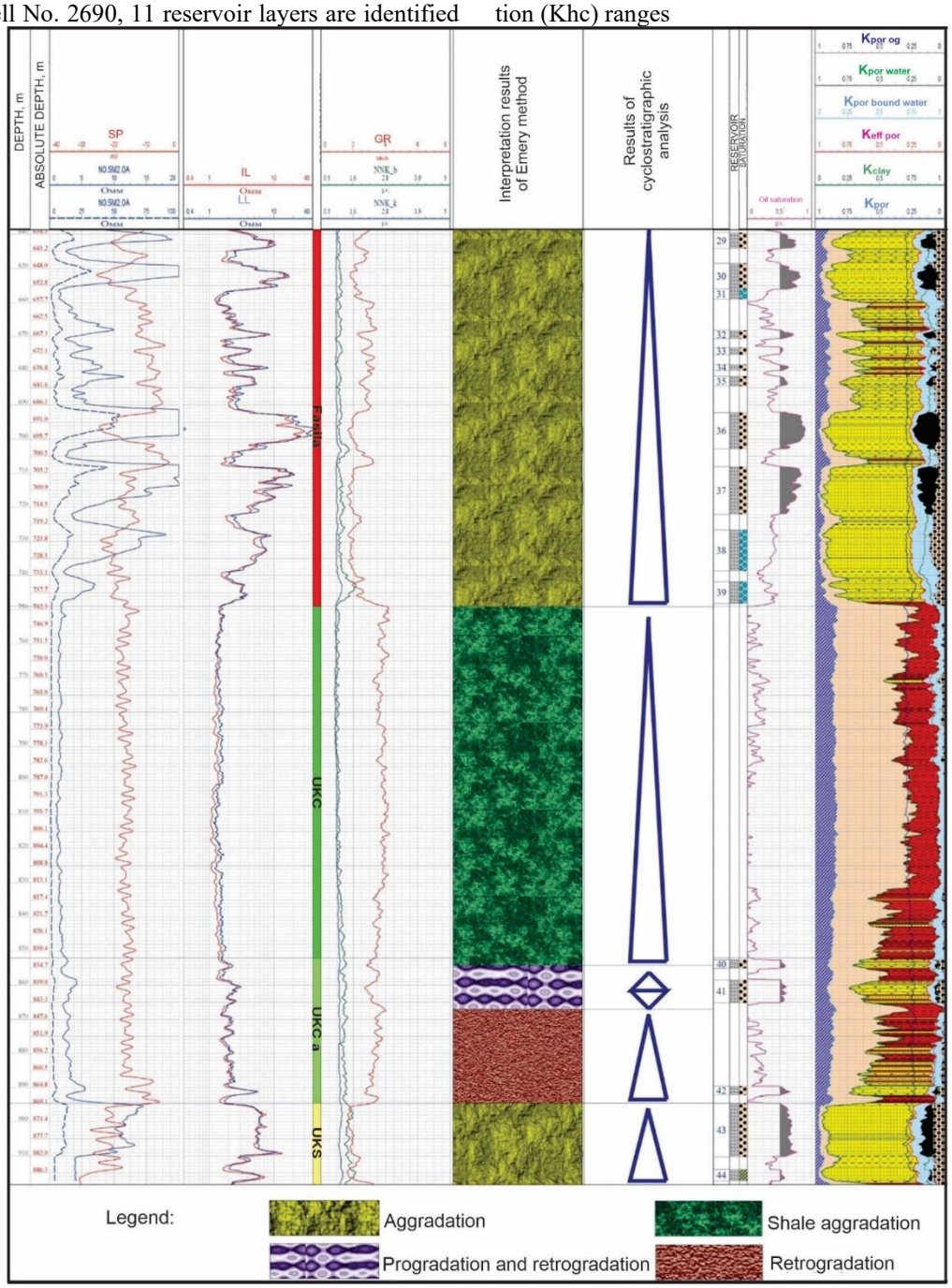


Fig. 3. Results of Emery and cyclostratigraphic interpretation of the Upper Kirmaky Sandy, Upper Kirmaky Clay, and Fasila Suite in well Neft Dashlary No. 2690

from 0.322 to 0.806, the average porosity (Kp) is 0.217, and permeability ranges from 0.034 to 0.183.

The Balakhany Suite consists of medium- and coarse-grained quartz sands and sandstones with a clayey matrix. The sand content of the section is 50–60%. Within this group, the X, IX, VIII, VIIa, VII, VI, and V sandy horizons are distinguished from bottom to top (Fig. 4).

The X horizon is composed mainly of sands and sandstones, with a thickness of 30–70 m and an average of 50 m. The depth interval 522.5–540.3 m is water-bearing, while the remainder of the horizon is fully hydrocarbon-bearing. Progradation, progradation–retrogradation, aggradation, and retrogradation are observed in the X horizon (Fig. 4). The average hydrocarbon saturation (Khc) is 0.564, porosity (Kp) ranges from 0.150 to 0.223, and permeability from 0.017 to 0.130.

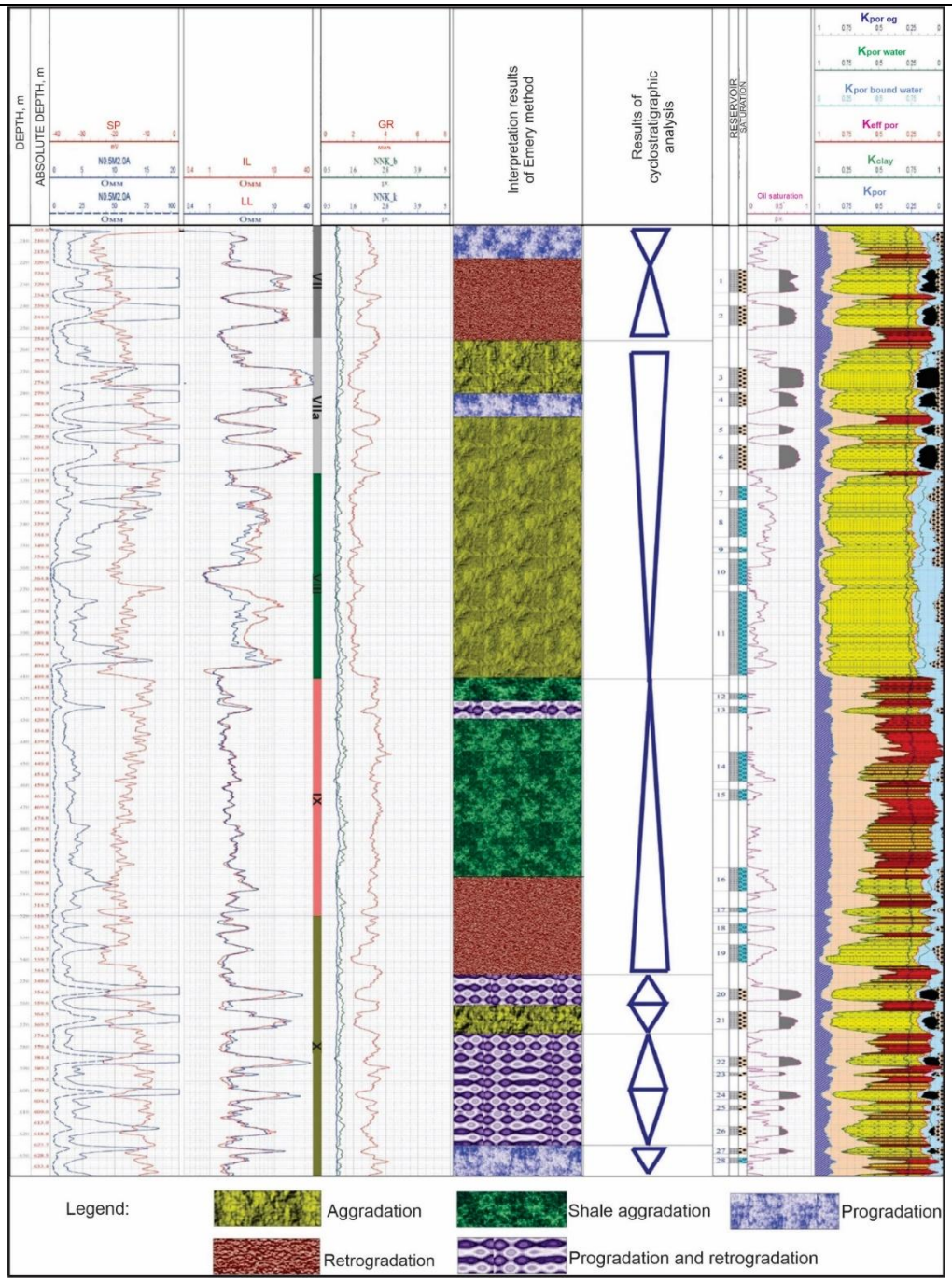


Fig. 4. Results of Emery and cyclostratigraphic interpretation of horizons X–VII of the Balakhany Suite in well Neft Dashlary No. 2690

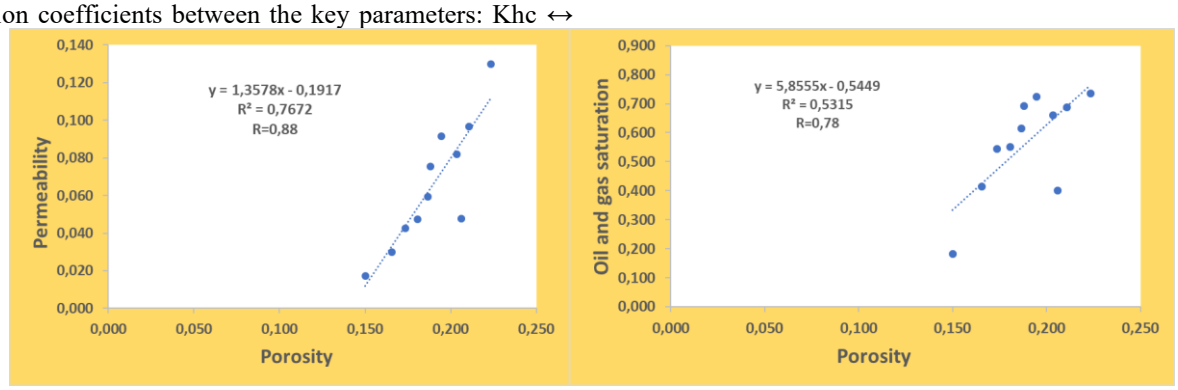
The IX horizon consists of fine- and medium-grained sands and sandstones with a clayey matrix. The sand content is 60%, thickness ranges from 38 to 70 m, with an average of 55 m. Six reservoirs are identified within the IX horizon, all of which are water-bearing. Within the horizon, retrogradation transitions upward to clay aggradation (Fig. 4). Permeability ranges from 0.018 to 0.050, average porosity (Kp) is 0.182, and Khc is 0.264.

The VIII horizon consists of fine- and medium-grained sands, sandstones, and clays, and is entirely composed of water-bearing reservoirs. Continuous aggradation is observed in the horizon (Fig. 4). Permeability ranges from 0.042 to 0.060, average porosity (Kp) is 0.224, and hydrocarbon saturation (Khc) is 0.368.

The VII horizon is represented by alternating layers of sand and clay, with sands predominating. Its thickness ranges from 32 to 70 m, with an average of 57 m. Within the horizon, retrogradation at the base transitions upward to progradation. The VIIa sandy layer, 30–70 m thick (average 50 m), is present at the top of the horizon. Both Horizon VII and the VIIa sandy layer are composed of oil-bearing reservoirs. Within the sandy layer, aggradation occurs at the base and top, while progradation dominates in the middle part (Fig. 4). Calculations show that average porosity (Kp) is 0.225, permeability ranges from 0.074 to 0.107, and hydrocarbon saturation (Khc) is 0.666.

At the next stage of the study, a regression analysis of the X horizon of the Balakhany Suite in well No.

2690 was carried out. Graphs of Khc versus Kp and permeability (Kpr) versus Kp were plotted and analyzed (Fig. 5). The regression analysis revealed high correlation coefficients between the key parameters: Khc ↔ Kp (R = 0.78) and Kpr ↔ Kp (R = 0.88), indicating robust relationships between porosity, permeability, and hydrocarbon saturation.



a *b*

Fig. 5. Graphs showing (a) hydrocarbon saturation (Khc) versus porosity (Kp) and (b) permeability (Kpr) versus porosity (Kp) (for the X horizon of the Balakhany Suite)

Conclusion

A comprehensive analysis of the petrophysical and lithofacies characteristics of the Productive Series of the Neft Dashlary area has shown that the hydrocarbon-bearing deposits comprise horizons VII, VIIa, and X of the Balakhany Suite, the Fasila Suite, UKCa, KS-2, and LK-1, LK-2 upper, and LK-2 lower.

The study of well logging data using the Emery method enabled the reconstruction of the main depositional conditions of the Productive Series in the Neft Dashlary area. The cyclicity of the section was examined using cyclostratigraphic analysis of the acquired materials. Reconstruction of depositional environments indicated that the formation of oil and gas accumulations occurred under progradational–retrogradational and aggradational conditions, which determine the spatial distribution of productive facies and the patterns of reservoir formation.

Regression analysis of the X horizon in well No. 2690 revealed stable correlations between porosity, permeability, and hydrocarbon saturation, thus enabling reliable assessment of reservoir quality.

Therefore, the combination of lithofacies analysis and petrophysical characterization not only allows the identification of highly productive horizons but also facilitates the prediction of their quality, providing a basis for optimizing field development.

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ECONOMIC SCIENCES

INTEGRATED RISK MANAGEMENT SYSTEM OF A BANKING GROUP

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Abstract

The article examines the conceptual foundations and structural elements of an integrated risk management system within a banking group. The purpose of the study is to systematize the key components, objectives, and governance principles of integrated risk management and to demonstrate its role in ensuring the financial stability and strategic sustainability of a banking group. The research is based on the analysis of theoretical approaches to risk management in financial institutions, international regulatory principles, and methodological frameworks applied in banking practice. The study uses methods of system analysis, comparative analysis, and structural modelling to identify the main elements and functional interrelations within the integrated risk management framework. The results of the study show that an effective integrated risk management system should operate simultaneously at the level of the entire banking group and at the level of its individual entities. The system integrates processes of risk identification, assessment, monitoring, reporting, and response, while also supporting risk-oriented decision-making and risk-adjusted performance evaluation. Special attention is paid to the role of corporate governance bodies, the definition of risk appetite, the development of a unified system of risk indicators, and the establishment of internal regulatory documentation and communication channels. The study concludes that the implementation of an integrated risk management system based on unified principles, methodologies, and information systems allows banking groups to maintain an optimal balance between profitability and risk exposure, improve the quality of managerial decision-making, and strengthen overall financial stability.

Keywords: integrated risk management, banking group, financial stability, risk appetite, corporate governance, risk monitoring.

The integrated risk management system of a financial group and/or a specific type of financial group and/or a banking subgroup (hereinafter referred to as the “Group”) constitutes a set of interrelated components whose interaction enables the achievement of the Group’s objectives and the fulfilment of its risk-management tasks. The components of a risk management system include the functions of the risk management system, the organization of that system, risk management processes, as well as the approaches, methodologies, tools, and information systems used within those processes (1).

The integrated risk management system operates at the level of the entire Group as a whole and at the level of its individual entities. The risk management system simultaneously functions at the level of the aggregate risk of the Group and its entities, as well as at the level of certain types of risk assumed by the Group and its entities. The approaches, methodologies and tools of the risk management system at the level of aggregate risk and certain types of risk should be presented in separate regulatory and methodological documents of the Group and its organizations, taking into account their technical complexity, diversity, and the need to regularly review them in the process of improving the risk management system.

The main objectives of the Group's integrated risk management system are to ensure the required level of financial stability of the Group and its entities, to ensure that the Group's risk profile corresponds to the strategic parameters of the Group's activities, and to develop and maintain a system of risk-response measures that is consistent with the profile and scope of the Group's operations.

Financial stability (2) is understood as the Group’s ability to meet its obligations to third parties in full and in a timely manner; the adequacy of its equity capital to cover both expected and unexpected losses resulting from the realization of risks, with a probability that ensures the maintenance of solvency; the compliance of the Group’s activities and those of its entities with the prudential standards and requirements of the national regulatory authorities of the countries in which they operate, including requirements related to capital adequacy of the Group and its entities; the presence of a balanced structure of assets and liabilities that ensures the necessary level of return on shareholders’ equity.

As for the compliance of the Group's risk profile with the strategic parameters of the Group's activities,

it is ensured through monitoring the actual values of risk indicators and taking appropriate response measures when critical thresholds of risk indicators are reached.

A risk-response system (3, 4) is understood as a set of tools, the use of which makes it possible to influence the level of various types of risks. These tools should enable the reduction of the level of expected and/or unexpected losses associated with selected risks. The system of measures includes, in particular, hedging, diversification, insurance, limit-setting, and other tools. The system of risk response measures also includes a set of criteria that allow timely decision-making regarding the appropriateness of applying specific tools and determining which of them is most effective.

The key objectives of the integrated risk management system are (1):

- Defining risk appetite, which results in defining the Group's target level of financial stability and the aggregate level of risk that is acceptable to the Group in line with its strategy.
- Risk identification, i.e. the identification of risks that may affect the Group's current or planned operations.
- Risk assessment, that is, the qualitative or quantitative evaluation of expected and unexpected losses associated with each identified risk, the probability of incurring such losses, as well as the assessment of the aggregate level of risk assumed or planned to be assumed by the Group.
- Determining the amount of capital required to cover expected losses. This is an assessment of the amount of capital required by the Group to cover expected losses caused by the realization of the risks assumed by the Group (for the entire Group, for each entity within the Group, for each line of business).
- Determining the amount of capital required to cover unexpected losses. It is an assessment of the amount of capital required to cover unexpected losses caused by the realization of the risks assumed by the Group (for the entire Group, for each entity within the Group, for each line of business).
- Participation in risk-oriented decision-making. Supporting strategic and tactical decision-making processes by analyzing the impact of those decisions on the level of risk assumed by the Group, by informing the results of the analysis to those responsible for decision-making.
- Defining the target risk profile. Based on the Group's business strategy and plans, the Group's risk profile must be defined to ensure adherence to the established risk appetite.
- Establishment of a communication system. This includes the creation of communication channels that ensure the collection, processing and dissemination of risk-related information to all stakeholders. Maintaining a unified system of indicators for measuring risk levels; implementing and maintaining the information systems necessary for the operation of the communication channels.
- Creation of a permanent risk monitoring system. Development of a system of indicators that allows for constant monitoring of the current risk profile, in particular, allow assessment of the acceptability and justification of the level of each type of risk, as well as monitor the compliance of the aggregate risk level with the established risk appetite.
- Risk reporting. This is the determination of actual values of risk indicators, the preparation of a report and its presentation to stakeholders, which makes it possible to assess the actual level of the Group's risk, the concentration of risks, the compliance of the types and levels of risks accepted with the target risk profile, as well as the compliance of the actual level of aggregate risk with the established risk appetite.
- Identifying accessible methods for managing risk and evaluating their effectiveness. This is the formation of a set of tools that can be used to influence the level of various types of risks accepted, as well as assessing the effectiveness of their use, taking into account the cost of application and/or the foregone profit associated with refusing to accept the risk.
- Timely response to risk, which involves identifying situations that require taking measures to influence the level of risk and to select the most effective tools for this.
- Risk-adjusted performance evaluation. Assessment of the effectiveness of activities, taking into account risk. The assessment of the various entities of the Group and their individual areas of activity, taking into account both the financial results obtained and the level of risk they accept in order to make a profit, as well as the volume of economic capital allocated to these entities and aimed at covering unforeseen losses due to the impact of risks. The assessment of strategic initiatives and new projects, taking into account their impact on the level of risk to which the Group is exposed.
- Creation of an internal regulatory documentation system for risk management. The creation of effective risk management processes and procedures that ensure an integrated approach to managing all risks of the Group, as well as the documentation of these processes and procedures through an internal regulatory documentation system.
- Monitoring compliance with the requirements for internal risk management regulatory documentation. It involves overseeing the implementation of the risk management processes and procedures set forth in the internal documentation.
- Improvement of risk management processes. This is the assessment of the effectiveness of risk management processes, including verifying the implementation of all assumptions underlying the risk assessment methodologies, implementing measures to improve the quality of risk management based on the results of the assessment of the effectiveness of risk management processes.

The Integrated risk management system combines both the Group's risk identification and actual risk assessment functions, as well as preventive risk management functions. Accordingly, governing bodies and departments ensuring the operation of the risk management system exercise control over the compliance of the risk level with the established restrictions, as well as participate in the adoption of

management decisions at various levels that affect changes in the risk level in the future.

The participation of the bank's Board of Directors, its Management Board, and the bank's specialized committees in the risk management system must be implemented through the following principles (1, 5):

- Management decisions must be made with due consideration of their impact on the level of risk affecting the Group and its entities.
- The Board of Directors is responsible for the overall risk management performance of the Group. The Board regularly monitors the risk level, which the Group adopts based on both aggregate risk indicators and reports that include qualitative and quantitative indicators of different types of risks.

The Bank's Board of Directors, the bank's management, and the bank's specialized committees: as bodies authorized to exercise oversight within the Group, have the ability through corporate governance procedures to exercise oversight over the activities of subsidiaries, the state of the risk management system and its effectiveness, based on reports on the level of risks taken by the Group and on breaches of the limits set by the risk appetite. Risk management processes are integrated into strategic planning and management processes. In particular, the development of the strategy and the definition of priority development directions and strategic objectives are carried out taking into account the balance between the desired profitability and the magnitude of the risks taken by the Group. The impact of the strategic decisions taken on the risk profile of the Group, individual entities of the Group, as well as other indicators of the Group's risk level is subject to discussion.

Risk management is a continuous process that must be integrated into the processes carried out by the organizations and units within the Group, including:

- Integration should be implemented through strict documentation of processes and operations and the inclusion of control procedures in them, which make it possible to prevent violations of the restrictions set on the risk level, as well as to monitor the actual level of risk. Specifically, a system of risk indicators is implemented, and permissible values that these indicators can assume are being proposed.
- The authority to accept each type of risk should be assigned to the management bodies, managers and employees of all levels of each organization of the Group. The distribution of authority and responsibility for accepting risks between collegial bodies, as well as managers and employees of different levels of management, should be carried out in accordance with the Group's strategy and the corporate governance principles adopted in the Group.
- The effectiveness of risk management at the level of business processes must also be ensured by all employees taking into account the risks associated with their decisions or actions, as well as by defining their responsibility for complying with risk management standards and procedures.

The Group must have a unified integrated risk management system, through which risks that could affect the operation of the any of the organizations within the Group are managed.

Risk management processes based on unified risk management principles should be implemented in all organizations within the Group and unified risk assessment methodologies should be used, taking into account their affiliation with the type of organization. Moreover, each organization's risk management processes must be sufficiently adapted to the specifics of its business and take into account the specifics of the risks to which it is exposed.

The Group must implement a risk management system that can have a significant impact on the activities of its constituent organizations. The management of risks inherent to financial organizations is of primary importance: credit risk (including country risk), market risk (including price, currency and interest rate risks, as well as market liquidity risk), liquidity risk, operational risk, legal risk, reputational risk, compliance risk and strategic risk. The principles, approaches, methodologies and tools for influencing the level of risks listed above should be developed for the entire Group and adapted for each of the Group's financial institutions, thereby achieving uniformity of technical means and methodological approaches to risk management in the Group.

The independence of the risk management department can be ensured by implementing the following principles (1, 6):

- The Group must have a department that coordinates the risk management of the Group's entities. This department is independent of the departments carrying out operational activities, which is ensured by its inclusion in the risk management unit, which is directly subordinate to the sole executive body of the Group's parent organization (the chairman of the bank's board).
- Risk management departments within the Group's organizations must be independent of other departments within those organizations and must conduct their activities in accordance with the Group's risk management standards, as well as report information about the results of their activities to the department coordinating the Group's risk management.
- Within the Group, responsibility for coordinating the management of legal risk, business reputation risk, and compliance risk should be placed on the bank's relevant departments, which carry out the methodological coordination of the Group's risk management activities. These departments should be responsible for the development and implementation of legal risk, reputational risk management policies and compliance risk policies, as well as for the implementation of these risk management processes at the Group and its individual entity levels. The responsibility for coordinating strategic risk management should be placed on the bank's division that performs this function both at the bank level and at the level of its subsidiaries and affiliates.

Independent oversight of the risk management system to assess its effectiveness and verify compliance

with and full implementation of risk management procedures should be carried out periodically by the internal control/audit departments of the Group and its constituent entities. The oversight is carried out both at the Group level and at the level of each constituent entity. The objects of control are both risk management processes and those elements of risk management that are integrated into strategic management and other operational processes.

The overall effectiveness of the risk management system is overseen by the Bank's Board of Directors and the Management Board based on regular reports that must be provided by the Group's risk management coordination unit, as well as the Group's internal control/audit unit, based on the results of inspection activities.

Findings. The study demonstrates that an effective integrated risk management system should function simultaneously at the level of the banking group as a whole and at the level of its individual entities. Such a system integrates risk identification, assessment, monitoring, reporting, and response processes into strategic planning and operational management. Particular attention is paid to the definition of risk appetite, the development of a unified system of risk indicators, risk-adjusted performance evaluation, and the role of corporate governance bodies in overseeing risk exposure. The integration of these elements ensures consistency between the group's risk profile and its strategic objectives.

Originality/value. The paper proposes a structured approach to organizing integrated risk management in banking groups, emphasizing the coordination of risk management processes, unified methodologies, and corporate governance mechanisms. The proposed framework contributes to improving managerial decision-making and strengthening the financial stability of banking groups.

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HISTORICAL SCIENCES

AZERBAIJAN'S POLITICAL RELATIONS WITH KAZAKHSTAN

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Abstract
The article states that the peoples of Azerbaijan and Kazakhstan have had common traditions, linguistic roots and cultural values for centuries. These common values were promoted on a wider scale during the period of independence. Inter-university cooperation, student exchange, cultural festivals and joint events have increased the closeness between the peoples. Organizations established to strengthen the unity of the Turkic world, in particular the Organization of Turkic States, have added an additional strategic dimension to the relations between Azerbaijan and Kazakhstan. Decisions taken within the framework of this organization have supported the joint development of the two countries in the political, economic and cultural spheres.

Keywords: Azerbaijan-Kazakhstan relations, period of independence, cultural-humanitarian relations, regional cooperation cultural relations, cooperation

Azerbaijan's political relations with Kazakhstan are characterized as one of the most stable and strategic partnership-based relations of the post-Soviet period. After Azerbaijan gained independence, Kazakhstan was one of the first Turkic-speaking states to recognize it. This recognition formed the basic principles of future political cooperation between the two countries. Both states established diplomatic relations and opened their embassies in a short time. The establishment of diplomatic relations created conditions for further intensification of political dialogue. Azerbaijan and Kazakhstan, as states that respect the norms and principles of international law, have based their political relations on supporting mutual sovereignty and territorial integrity. Kazakhstan has always openly supported the territorial integrity of Azerbaijan. This support has been particularly evident in the Karabakh issue. Azerbaijan has also consistently supported Kazakhstan's political initiatives and regional stability policy. Both countries have played a key role in strengthening political solidarity among Turkic-speaking states. The Organization of Turkic States has provided a broad platform for strengthening political relations. Azerbaijan and Kazakhstan, as important members of this organization, have actively participated in joint decision-making. The presidents of the two countries have regularly held political consultations. These meetings were of great importance in terms of both the development of bilateral relations and the discussion of regional issues. High-level relations between Ilham Aliyev and Kassym-Jomart Tokayev are one of the main factors for the strength of political relations. Nursultan Nazarbayev's special attention to relations with Azerbaijan in the previous period played a major role politically. He assessed Azerbaijan as a strategic partner among Turkic-speaking states. The Azerbaijani side also highly appreciated Nazarbayev's contributions to Turkic unity. Cooperation in the political sphere was further strengthened with the signing of bilateral documents. Strategic partnership agreements occupy a special place among these documents. Both states consider it important to establish peace in the region. To this end, they actively cooperate within the framework of international organizations. The two countries have supported each other on various political issues within the framework of the UN, OSCE and OIC. Kazakhstan positively assessed Azerbaijan's hosting of international events. Azerbaijan, in turn, supported Kazakhstan's international peace initiatives. Both countries perceive the security of the Central Asian and South Caucasus regions as interconnected processes. One of the important directions of political relations has been the activity of bilateral commissions. These commissions have contributed to the coordinated resolution of interstate issues. Azerbaijan and Kazakhstan have further deepened their political relations with regional energy and transport projects. These projects have transformed political cooperation into a partnership based on mutual interest. The two countries have always taken the same position on issues related to the Caspian Sea. Cooperation between Azerbaijan and Kazakhstan has been of particular importance in determining the legal status of the Caspian. At the summits of the Caspian littoral states, both countries have taken important steps to deepen political dialogue. One of the factors strengthening political relations is common international positions.

The strength of Azerbaijan's political relations with Kazakhstan stems from their commitment to common goals. Both states have pursued policies based on the principles of peace, security, and mutual respect.

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JURISPRUDENCE

THE EMPLOYEE UNPROTECTED LEGAL POSITION AND VAGUE NORMS OF GEORGIAN LABOR LAW COD (COMPARATIVE ANALYSIS)

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Abstract

The given paper is the analysis of the employee legal position in working relations, systemic research of Labor Law Code of Georgia corresponding norms, and evaluation of court practice. On the base of this research problematic issues are identified, which ensue after essential change in the working contract of the employee and voluntary dismissal from work in the legal definition process.

The research showcases , that in practice there still exist many leading cases which are not solved generally and effectively within the framework of the active law. Those problems are especially clearly established in the court practice analysis. Also , France and Germany Labor law codes and corresponding court practice in relation to the existing problematic issues are discussed.

In the conclusion to the paper there are evaluations and recommendations on the identified shortcomings with the aim of their eradication, - amongst them , clarification of the legal norms and the improvement of institutional mechanisms in working relations regulation sphere.

Keywords: employer, employee, main conditions change, conscientiousness, reality of the will.

1. Introduction

Working contract is an essential legal tool in working relations, , one of its main functions is the fair balance of the parties' interests. . The employer interests are to ascertain effective organization of the labor process, functioning of the enterprise, and achievement of the economic goals, while the employee interests are confined to the working place stability, safety, dignified working conditions, and also personal dignity respect. Balancing of these contradictory interests is precisely the working contract meaning.

According to the provision 26 of Constitution of Georgia working freedom is provided by labor freedom and other social rights which are connected to human basic interests and the main condition of achieving basic rights. "Labor is free ", that according to the definition of the Constitutional court of Georgia "means that a human being has a right to decide how to employ his capabilities in the working process, choose this or that sphere of working activity, the labor freedom means that the state takes care of providing its citizens with work and protects their working rights. Constitution not only protects the right to choose the work, but also the right to implement, save and terminate this work.

(Constitutional Court of Georgia. (n.d.). *Decision on the case No. 2/2-389)*

In the working relations regulation context of special interest are following questions :

1. Legal nature of the working contract main conditions change – how changes must be carried out, so that parties' rights and conscientiousness principle be protected.

2. Legal grounds for employee's voluntary dismissal, especially in those cases when the formal statement may in reality be caused by the employer's initiative.

Actuality of the aforementioned issues dictated the main objective of the research:

Systemic analysis of the Labor law code of Georgia norms, definition of existing legal shortcomings and provision of recommendations for protection of the employee's rights incase of working contract main conditions change and voluntary dismissal.

Sources and Methods

Main sources of the paper are Labor law of Georgia, Constitution of Georgia, Civil law of Georgia, as well as, entire court decisions of Georgia, Code travail of France, Civil law (BGB(of Germany, established doctrinal and normative approaches.

In the comparative-legal analysis the paper is based on the EU Labor law standards, Labor law of Germany and France, as well as, developed models which are characterized by working contract distinct dogmatic construction and the high degree of the employee protection.

To correctly define problematic issues related to this given topic it is important to employ court cases practice, as well as, the comparative analysis of the foreign countries legislation. The analysis clarifies the current reality of how general courts of Georgia and courts of foreign countries make decisions on labor regulatory issues, as well as, what shortcomings exist in that relation. The research employs relative legislation and practical leading cases analysis methods. Comparative law method and practical (leading cases) analysis methods are used in the research, which provides balanced evaluation of theoretical, and practical results.

2. THE WORKING CONTRACT ESSENTIAL CONDITIONS

The doctrine and the practical meaning of the concept – In the courts of general jurisdiction the litigation between the employer and the employee is regulated according to Labor law of Georgia, which defines legal regulatory norms. "Labor law of Georgia unequivocally points out that working relationship issues not de-

cided by the law or other special law are regulated according to the norms of Civil law of Georgia" (Labor Law of Georgia, 2010, p. 1).

Main foundation and legal regulatory mechanism of the working relations between the employer and the employee is the working contract which stipulates working contract essential conditions for the employee.

Labor law of Georgia does not directly define working contract "main conditions " list. Analysis of the normative framework and court practice basis working contract main conditions are defined by core elements of working relations, i.e. working function, working payment, working place and time.

Main conditions working contract change is possible only by both parties agreement:

Change by the unilateral decision of the employer which worsens the employee's situation, is viewed by the court practice as termination of the working contract by the employer's initiative and leads to certain legal results. It is possible to say definitely that working conditions change can be estimated as fair, only in case if the employee agrees with them.

Notwithstanding existence of court practice the real challenge is that Labor law of Georgia does not specify how the employee should express consent upon working conditions change. In practice this results in law defining issues and possible law disagreement. Besides leading cases part states a problem ,if moral and undocumented consent of the employee confirms the agreement, or whether the employee's silence on the main working conditions change can be interpreted as a consent.

3. COURT PRACTICE: THE MAIN CONDITIONS CHANGE AND THE EMPLOYEE'S SILENCE

Although there is an existing description of the main conditions change issue in the Labor law of Georgia, it does not specify the form of the employee's consent. Therefore court's position is of special interest and its lawsuits interpretation context, where the parties have actual disagreement on working conditions change facts which are estimated in relation to the legal results.

It must be said that basic problem in working relationship is "Concludent consent"in relation to working conditions change as it does not specify if silence or behavior can be considered as a consent, except in only specific and rare occasions.

Labor law of Georgia does not acknowledge concludent consent in relation to working conditions change; which the court fills by general civil principles and conscientiousness standard.

The employee appealed to court on main working conditions change and asked to compel the employer to pay unreceived wages.The employee stated that the employer had changed the main working conditions/ payment five years ago and had not notified the employee , neither negotiated that payment change.

The employer's position: the employer explained that he had definitely changed the employee payment five years ago and the latter had been informed and continued to work for that changed payment, thus his silence was assessed as a consent.

The court did not satisfy the employee's claim. The court decided that the employee had concludently expressed consent on the changes. The court highlighted the importance of conscientiousness principle and stated:

In civil exchange conscientiousness is extremely important. Entire law and order are founded on the conscientiousness principle for the legal subjects rule of behavior and this principle is viewed as a normative concept. Adjusted to market economics private law establishment process in the developed countries has highlighted the importance of " conscientiousness" principle , which forms civil exchange pivot and become the cornerstone of the entire civil exchange. Civil law of Georgia has also acknowledged conscientiousness as a legal value. Fairness and stability of the civil exchange depends upon its participants conscientiousness. Its essential function is the ensuing of the fair outcome and at the same time avoiding blatantly unfair results, by means of which stability and equilibrium in civil exchange are achieved. (Supreme Court of Georgia. (2024, May 1). *Decision on the case No. 125-2024*.)

It is observed in Georgian court practice that conscientious behavior obligation is based generally on conscientious supposition. This supposition defines the main direction of legal relations, not the juxtaposition of the parties' interests but their solidarity as the basis of normal civil exchange. Conscientiousness is not only the right but also supposition of the obligation fulfillment. Definition of unconscientious behavior is the assessment of the concrete facts and should be decided by judge in every concrete case with regards to the factual circumstances. This process of assessment by the judge is quite complex and requires great observation as conscientious request has no absolute advantage with regard to the contractual freedom and it is not admissable to base each assumption on abstract principles foundation. It is necessary to consider specificity of each concrete case. Conscientiousness principle as the leading principle of civil exchange is included in many provisions of the Civil law of Georgia. Thus conscientiousness principle of behavior in the general private law relations. (Batumi City Court. (2025, June 6). *Decision on the case No. 2-1711)*

According to the Civil law of Georgia the will could be expressed or concludent; although Labor law is a social law, whereas Civil law norms are used only subsidentally and restrictively. Therefore active in Civil law general model of concludent will should not be automatically transferred to working relations.

Though Labor law of Georgia is based upon the employee's consent principle , it less dogmatically regulates the essential working conditions change issue.

Therefore we come to the conclusion that Labor law of Georgia should have a distinct description that would define the employee's consent in main working conditions change.

"Working contract main conditions change demands employee's distinct consent" (Zeneishvili, A. (2015) *Comments on the Georgian Labor Law Code*. Tbilisi), although Labor law code of Georgia less dogmatically regulates main conditions change issue.

Given this, we come to the conclusion that the Labor Code of Georgia should include a clear provision that precisely defines the employee's consent to changes in essential terms.

4. ESSENTIAL WORKING CONDITIONS CHANGE AND SILENCE OF THE EMPLOYEE ACCORDING TO THE LEGISLATION OF GERMANY AND FRANCE

Labor law of Germany distinctly differentiates between contract change and contract termination.

The employer's managerial power gives him opportunity to change working place organization details, though if change trespasses these limits and affects working function, payment, working time and place, it is considered a contract essential change and demands the employee's consent.

In German contract law, silence is generally not a form of expression of will and cannot be considered as consent to a change in the contract or its essential terms. Medicus, D., & Lorenz, S. (2015). *Schuldrecht I: Allgemeiner Teil* (21st ed.). C. H. Beck.

"In case of the employee's refusal , the employer can terminate the existing working contract, but this is possible only if social and proportionate justification is provided" (Richardi, R. (2019). *Arbeitsrecht* (7th ed., p. XX). C. H. Beck).

Labor law of France strictly differentiates the contract change and the working conditions change. Payment, working place and time, professional status change are considered the essential change of the contract. Such changes are admissible only with the employee's consent.

Employee's refusal(no(to essential change does not constitute disciplinary disruption and the employer has a right to terminate the contract only in case of a real and serious reason.

Civil law of Germany acknowledges on the whole that silence does not imply consent on the main working conditions change- preliminary, active and expressed will is essential for any contract (or its conditions) for change to be valid. Discussion about extraordinary cases notwithstanding, active principle, in case of existence of specific conditions discarded silence may be viewed as consent. But this is an exception and it occurs only in court restricted explanation according to concrete, predefined rules-not in general. According to German Labor law the employer's consensual (Weisengsrecht) does not encompass main conditions of the working contract. Change in the working conditions is possible only on the grounds of the employee's distinct expression of will, which excludes the opportunity of conclusion on consent according to silence or factual behavior. Müller-Glöge, R., Preis, U., & Schmidt, I. (Eds.). (2024). *Erfurter Kommentar zum Arbeitsrecht* (24th ed.). C. H. Beck.

"Labor law of France strictly differentiates the contract change and the working conditions change. Payment, working place and time, professional status change are considered the essential change of the contract. Such changes are admissible only with the employee's consent." (Pélissier, J., Supiot, A., & Jeammaud, A. (2022). *Droit du travail* (28th ed.). Dalloz.

In Labor law of France silence does not constitute voluntary consent on working contract status or main conditions change, if any project/contract the accountable party does not have deliberate and active confirmation of consent.

In Labor law of France the pivotal principle is: contract or main working conditions change requires yes or no- or active, expressed consent. Silence, in this case, is not considered a potent consent. French court practice and legal comments define: employee's silence if it is not specific, blatant consent, should not be considered as consent on the contract change. Silence, as Pelissier, Supiot and Jeammaud point out cannot be considered as consent, especially if the employee is under economic and psychological pressure conditions. If the employee, after essential conditions contract change still continues work in his place or does not express his opinion - this does not signify consent, it is not in the process of contract condition change received consent.

"In Labor law of France the usual practice is: the employer gives the employee notice on the conditions change, concrete date for answer and each answer must have concretely expressed will (yes or no) . In that process silence is not viewed as consent" (Lyon-Caen, G., & Lyon-Caen, A. (2021). *Droit du travail* (27th ed.). Dalloz)

Germany and France's models provide legal definition and distinct boundaries in relation to main working conditions change than Labor law of Georgia does not.

5. THE EMPLOYEE'S VOLUNTARY DISMISSAL-REASONS, LEGAL PROBLEMS AND THE EMPLOYER'S ROLE

"According to article 47 subsection "D" of the Labor law of Georgia the reason for termination of working contract is the employee's state/work by his own will using the application in written form". ([1]Labor Law of Georgia. (2010))

According to this legal formulation of the working relations the employee's writing of the application is traditionally considered as a voluntary decision and the employer's legitimate reason for working relations termination. But in practice we often come across such reality when this decision was neither voluntary, nor deliberate and written under emotional stress, stress or in conflict situation.

The employee under Labor law of Georgia is entitled to a right to terminate working relations at any moment by a personal initiative. Thus labor law depends on general Civil law principles, mainly:

.freedom of the will;

.conscientiousness;

.reality of the will.

According to Civil law of Georgia voluntary will must be free, without error or coercion. If the will is formed in circumstances that seriously undermine deliberate decision (great emotional excitement, conflict, coercion) doubt arises on the potency of such will.

In practice there are many cases when the employee in a state of great emotional excitement writes an application where he requests to be dismissed from work. The employer reacts instantly and issues an order

of dismissal. Though the next day the employee asks to withdraw the statement of dismissal.

Meanwhile the employer had already issued the dismissal order and refuses to retrieve it.

It is true Labor law of Georgia does not state when the employer should react to the statement. Thus here we confront the most important concept of civil exchange the conscientiousness principle. In short, whether the employee had enough time to ponder on the decision, or whether the employer acted according to conscientiousness principle.

Conscientiousness principle defines in these circumstances the employer's initiative in defining the employee's position and also in determining the reasons for termination of the working contract. In the contrary case if the employer defied the conscientiousness obligation which is highly valued in labor relations. It is also important that when the employee asks to withdraw the statement, and states a concrete reason that it was written in the state of excitement. It can be assumed legally that it is the effort to eliminate the error of the will, as the will was not formed.

In these circumstances if the employer had information on the will's problematic nature, his categorical denial can be perceived as the violation of the conscientiousness principle. It seems the employer acted within the limits of the Labor law legal norms, as there was the employee's request of termination, the employer in his turn reacted instantly, but still whether it was an adequate response in correlation with legal norms, hence we have the conscientiousness principle violation on the employer's part.

The Supreme Court of Georgia has noted in a number of its decisions that. In working relations the employer has a heightened responsibility of conscientious behavior. On the employer's part: not determining the reasons for statement, ignoring the employee's emotional state, taking the decision instantly may be assumed as the conscientiousness principle violation.

Issuing a formal order does not preclude the obligation of ascertaining the will, especially when the employer has been informed that the decision of termination was taken on emotional grounds.

The working contract termination procedure may be initiated by the employee (e.g. the latter writes a statement of termination), but in reality this everything was instigated by the employer for following reasons: psychological pressure, deterioration of payment and working conditions, deliberate violation of the contract conditions by the employer. Kasradze, L. (n.d.). *Labor law* (p. 83).

"Therefore though initiative of termination comes from the employee, attention should be paid to the expression of the will. Hence the actuality of the expression of the will must be studied; in order to determine whether the employee dismissal was actually the employer's initiative." (International Labour Organization. (2017). *Labor law of Georgia and international legal standards* (p. 242))

6 .EXPRESSION OF THE WILL ANALYSIS IN THE LEGISLATION OF GERMANY AND FRANCE

A distinct standard is entrenched in the labor legislation of France: Cour de cassation,Chambre social decision of 21 March 2021 (case#19-17.919(states that termination of labor relations by the employee must be based on clear and not dubious will. Cour de cassation, Chambre social in decision of 24 March 2021 case # 384 declared that the employee's behavior or formal action could not change a distinct and wise will.

According to German legislation the will expression is invalid if it was taken under extraordinary psychological pressure, does not express the person's real will, there is a suspicion that the decision was not taken deliberately. Court practice of Germany (BAG/BGH) confirms that the termination statement should not be legally problematic, the employer has no right to use maliciously the employee's emotional weakness. According to German doctrine the employee has a right to confirm or withdraw the statement.

Actually we arrive at the conclusion that Georgian, German and French legislation unequivocally showcases the unique principle: the employee's statement should be true and not formal, the employee's will should be stated whether the employee's decision was sound or emotionally provoked. Only after determination of the will can the employer issue a dismissal order. The employer's instant reaction enhances legal risks as labor legislation objective is not the formal acts implementation but human being's will and dignity protection.

7. DISCUSSION of the RESULTS

It is possible to say, that according to the research in Labor law code of Georgia there exists legal void on the consent issue, although fairness evaluation by the court is based mainly on conscientious principle. International experience (France, Germany) shows that for silent agreement distinct, formal rules should exist, to protect employee's rights and lessen legal vagueness.

Court practice fills these shortcomings with conscientiousness principle, how conscientiously the employer behaved in relation to main conditions change and how conscientiously the employer acted in relation to the employee's dismissal.

As international practice demonstrates:

France Cour de cassation, Chambre social case # 19-17.919 of March 24 2021 underscores that silence or continuation of work does not express consent.

2. Germany: BAG/BGH practice admits that silence does not constitute will on working conditions change with the exception of extraordinary, distinct legal cases (BGH, xi ZR 139/23).

According to Labor law of Georgia, silence is not considered the employee's consent, though legislation does not define this issue in detail which creates legal vacuum. In Georgian law the labor relationship is often regulated by the conscientiousness principle which may help the court to establish so called silent cases. Though such an attitude does not provide sufficient legal definition and increases the litigation risks.

The cornerstone principle is: silence is not blatantly, directly, clearly expressed consent, whether the working rights are protected only and only by active, expressed will.

The research made clear that in Labor law of Georgia in voluntary dismissal process does not provide correct legal mechanism of the employee real will estimate. In practice we often come across of the situations when the employee in state of emotional instability writes a statement, and the employer instantly makes an order of dismissal, and does not find out such behavior seriously undermines the conscientiousness principle and increases litigation risks.

In the international practice (France Cour de cassation, Chambre social, 2021; Germany BAG/BGH) clearly showcases that employee's will should be free and deliberate , while the employer should show conscientiousness which presumes consultation with the employee, provision of information and extension of the time for reconsideration of the will.

8. CONCLUSION and RECOMMENDATION

It can be said in the conclusion, that existing norms of Labor law code of Georgia appertaining to working contract main conditions change and real evaluation of voluntary consent of the employee, are not defined in detail.

To eradicate the existing shortcomings it is necessary to clarify Labor code legal norms on main conditions change and expression of voluntary consent, as well as, improvement of institutional mechanisms that will provide the employee will's authenticity effective study process.

Implementing these changes will help to strengthen legal protection, working relations order and transparency and reduce litigation risks.

Labor law code of Georgia article 20, subsection 2 should be defined in a following way: "Working contract main conditions can be altered only with the consent of both parties. If working contract does not contain some principal condition, definition of such condition is possible by the employee's consent. The employer should notify the employee in a written form, while the employee in 7 days' time should submit an answer in a written form."

Labor law code of Georgia article 47 subsection 3 should state: "According to the subsection "d" of this article on the grounds of dismissal case, the employer must, from the point of view of voluntary decision, listen to the employee and give the latter time to reconsider his decision. Termination decision is valid only when it is established that the employee's will is free, and not the result of emotional stress or coercion.

Taking into account the above recommendations is a necessary prerequisite for the effective and consistent application of the norms of the Labor Code, which, in turn, ensures its systemic completeness and legal stability in terms of protecting the rights and legitimate interests of both the employer and the employee.

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MATHEMATICAL SCIENCES

MODELING PERIODICALLY FORCED HEAT WAVES IN INHOMOGENEOUS MEDIA VIA THE GENERALIZED FOURIER PRINCIPLE

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Abstract

This paper investigates the n-dimensional hyperbolic-parabolic heat conduction problem in inhomogeneous media under the influence of periodically forced thermal sources. The governing dynamics are described by a generalized Cattaneo-Vernotte type equation, supplemented by third-type generalized boundary conditions and initial Cauchy conditions. For the first time, this complex boundary value problem is solved by transitioning from classical Euclidean settings to an infinite-dimensional Hilbert space framework using the Generalized Fourier Principle. Unlike traditional numerical methods that rely on spatial discretization, our approach utilizes the spectral decomposition of the inhomogeneous operator, allowing for a precise analytical representation of heat wave propagation. The internal heat source is modeled as a time-periodic trigonometric Fourier series, enabling the study of steady-state periodic responses and resonance phenomena in functionally graded materials. The results provide a rigorous mathematical foundation for understanding finite-speed heat signals in complex media, offering a benchmark for future thermal shock analysis in advanced engineering applications.

Keywords: Hyperbolic-parabolic heat equation, İnhomogeneous media, Generalized Fourier principle, Hilbert space, Periodic forcing, Cattaneo-Vernotte model

Mathematics Subject Classification: 35K20, 35L20, 35P10, 47A70, 80A20

1. INTRODUCTION

In modern industrial complexes and technological systems-such as laser material processing, microwave heating, and aerospace engineering-the extremely high speed of heat propagation and periodic heat flow processes challenge the application of classical parabolic heat conduction models based on Fourier's law. The classical model assumes an infinite speed of heat propagation, which leads to physical inconsistencies when dealing with ultra-short time scales or high-frequency oscillations. To overcome these limitations, the general form of the hyperbolic-parabolic heat equation, based on the Cattaneo-Vernotte model, is analytically described. This model accounts for a finite speed of heat propagation by incorporating relaxation time, resulting in the emergence of wave-like thermal processes.

In inhomogeneous (non-homogeneous) media, the dynamics of these thermal waves become significantly more complex. When physical properties such as thermal conductivity and relaxation time vary spatially, heat waves undergo refraction, reflection, and interference at material interfaces or within gradient spaces. Most existing studies in this field are either restricted to homogeneous media or rely on standard numerical techniques such as the Finite Difference Method (FDM) or the Finite Element Method (FEM). Despite their utility, these methods can be computationally intensive in multi-dimensional spaces and often encounter difficulties in capturing the core spectral characteristics of the solution, especially under periodic forcing.

The primary objective of this work is the analytical and numerical modeling of periodically forced heat waves in multi-dimensional inhomogeneous media, governed by equations (2.1)−(2.4), using the Generalized Fourier Principle within the framework of infinite-dimensional Hilbert spaces. The scientific novelty of this research lies in the first-time application of a unique spectral decomposition approach based on a specific differential operator to solve this particular boundary value problem. By avoiding traditional matrix-based transformations, this method represents the solution as a series expansion of the operator's eigenfunctions. This approach not only ensures a rigorous analysis of resonance phenomena but also guarantees the stability and convergence of the solution within infinite-dimensional spaces.

The mathematical modeling of thermal energy transport has undergone significant evolution since the infinite propagation speed paradox of the classical Fourier law was first challenged. The fundamental equations used in this study are anchored in classical and modern scientific literature, integrating the theoretical foundations of mathematical physics problems.

Fundamental sections of the equations of mathematical physics, such as heat conduction and wave equations, are extensively analyzed [2, 15]. Problems

regarding the continuity of functions in Hilbert and Banach spaces, as well as the expansion of self-adjoint operators in terms of eigenfunctions and their application areas, have been studied [1, 3]. Methods for solving non-homogeneous boundary value problems and the general theory of partial differential equations are presented in a correlated manner in the literature [4, 8].

The general study of heat conduction processes, the propagation of heat waves in various media, and their similar and distinct characteristics are analyzed in detail [5, 7, 9]. The generalization of the classical Fourier law and the mathematical modeling of processes in non-equilibrium states demonstrate the features and significance of modern approaches [6, 10]. In recent years, the dynamic analysis of fractional-order thermal processes in non-homogeneous media [11, 14] and the analytical solutions for hyperbolic heat conduction in functionally graded materials [12, 13] are being intensively studied.

The methods of mathematical physics, particularly the application of the Fourier method to mixed boundary value problems and analysis through the theory of functions of a complex variable, are essential sources playing a vital role in this research field [16, 17, 20]. Solutions proposed for n-dimensional wave equations and the vibrations of mechanical systems (loaded strings) expand the practical applications of the theory [18, 19, 21]. The most recent research is focused on the modeling of heat conduction processes in n-dimensional parallelepipeds under zero Dirichlet conditions [22].

This paper aims to integrate these analytical techniques to investigate the spatio-temporal dynamics of heat waves in non-homogeneous media, utilizing the generalized Fourier principle to derive an explicit solution for the temperature field.

2. MATHEMATICAL FORMULATION

2.1. *Theoretical Framework* (*Hilbert Space Setting*)

The problem is formulated in an infinite-dimensional Hilbert space $H = L_2(\Omega)$, where $\Omega \subset \mathbb{R}^n$ is a bounded domain with a sufficiently smooth boundary $S = \partial\Omega$. The thermal state of the system is described by the function $U(x,t)$, which belongs to the space $L_2(0,T;\ H^1(\Omega))$.

Unlike classical parabolic models, this formulation accounts for the finite speed of heat propagation by treating the spatial non-homogeneity as a self-adjoint elliptic operator $\mathscr{L}$ acting within H. The inhomogeneous properties of the medium-thermal relaxation τ, damping $\alpha(x)$, and conductivity $K(x)$-are represented as bounded linear operators. By applying the Generalized Fourier Principle, we project the dynamics onto the basis formed by the eigenfunctions of the operator $\mathscr{L}$. This allows for the transformation of the partial differential equation into a system of decoupled second-order ordinary differential equations in the spectral domain.

2.2. *Governing Equations* (*Symbolic Representation*)

The mathematical model for periodically forced heat waves in a, inhomogeneous medium is defined by the following system:

The Governing Differential Equation**:**

The propagation of heat waves, considering the relaxation of the heat flux and spatial non-homogeneity, is governed by:

$$\tau(x)\frac{\partial^2 U}{\partial t^2} + \alpha(x)\frac{\partial U}{\partial t} - \sum_{i=1}^{n}\frac{\partial}{\partial x_i}\left(\sum_{j=1}^{n} K_{ij}(x)\frac{\partial U}{\partial x_j}\right) = f(x,t), \quad (2.1)$$

$$f(x,t) = \sum_{k=0}^{\infty} a_k(x)\cos(k\omega t) + b_k(x)\sin(k\omega t),\ x \in \Omega, t > 0$$

Generalized third-type boundary conditions**:**

The interaction between the medium and the external environment on the boundary S is defined by the Robin-type condition:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{n} K_{ij}(x)\frac{\partial U}{\partial x_j} n_i(x) + \beta(x)U(x,t)\right] = \psi(x,t), x \in S \quad (2.2)$$

Initial (Cauchy) conditions:

To satisfy the uniqueness of the hyperbolic system, the following initial state is prescribed at $t = 0$:

$$U(x,0) = U_0(x), x \in \Omega, U_0(x) \in H^2(\Omega) \quad (2.3)$$

$$U_t(x,0) = U_1(x), x \in \Omega, U_1(x) \in H^1(\Omega) \quad (2.4)$$

2.3. *Analytical Solution via Generalized Fourier Principle*

To solve the governing equation (2.1) for a, inhomogeneous medium, we employ the Generalized Fourier Principle, which involves expanding the solution into a series of eigenfunctions that inherently account for the spatial variation of the material properties.

Eigenvalue problem for the inhomogeneous operator: Before substituting the solution, we must define the appropriate basis functions. We consider the spatial differential operator $\mathscr{L}$ and solve the associated eigenvalue problem in the Hilbert space $H = L_2(\Omega)$:

$$\mathscr{L}\ \Psi_n(x) = -\nabla\big(K(x)\nabla\Psi_n(x)\big) = \lambda_n\Psi_n(x), x \in \Omega \quad (2.5)$$

with the homogenized boundary condition on S:

$$K(x)\nabla\Psi_n(x)n + \beta(x)\Psi_n(x) = 0. \quad (2.6)$$

The eigenfunctions $\{\Psi_n(x)\}_{n=1}^{\infty}$ obtained from (2.4)−(2.5) form a complete orthonormal basis, satisfying, $\langle\Psi_n(x), \Psi_m(x)\rangle = \delta_{nm}$

Substitution and modal decomposition:

We seek the solution $U(x,t)$ as a generalized Fourier series expansion:

$$U(x,t) = \sum_{n=1}^{\infty}\Psi_n(x)T_n(t). \quad (2.7)$$

Now, substituting the expansion (2.7) directly into the governing differential equation (2.1), we obtain:

$$\tau(x)\sum_{n=1}^{\infty}\Psi_n(x)T''_n(t) + \alpha(x)\sum_{n=1}^{\infty}\Psi_n(x)T'_n(t) + \sum_{n=1}^{\infty}T_n(t)\times$$

$$\times\left[-\nabla\big(K(x)\nabla\Psi_n(x)\big)\right] = \sum_{k=0}^{\infty} a_k(x)\cos(k\omega t) + b_k(x)\sin(k\omega t) \quad (2.8)$$

Using the relation from the eigenvalue problem (2.5), the term in the brackets is replaced by $\lambda_n\Psi_n(x)$. This eliminates the spatial derivatives of the unknown function.

Projection onto the Hilbert Space:

To decouple the equations for each mode n, we take the inner product of equation (2.8) with a test function $\Psi_m(x)$ over the domain Ω. Due to the orthonormality of the basis, we derive the system of ordinary differential equations for the time-dependent coefficients $T_n(t)$:

$\bar{\tau}_n T''_n(t) + \bar{\alpha}_n T'_n(t) + \lambda_n T_n(t) = F_n(t)$ (2.9)

where the modal coefficients and the periodic forcing term $F_n(t)$ are defined as:

$$\bar{\tau}_n = \int_\Omega \sum_{k=0}^{\infty} \tau(x)\, d\Omega, \bar{\alpha}_n = \int_\Omega \sum_{k=0}^{\infty} \alpha(x)\, d\Omega,$$

$$F_n(t) = \int_\Omega \sum_{k=0}^{\infty} a_k(x)\cos(k\omega t) + b_k(x)\sin(k\omega t)\Psi_n(x)\, d\Omega = \sum_{n=1}^{\infty} A_{nk}(x)\cos(k\omega t) + B_{nk}(x)\sin(k\omega t),$$

Periodic steady-state solution:

The general solution for each mode $T_n(t)$ consists of a transient part and a steady-state part. Given the periodic nature of the forcing function $F_n(t)$, the steady-state thermal response is:

$T_n(t) = \sum_{k=0}^{\infty} C_{nk}\cos(k\omega t) + D_{nk}\sin(k\omega t)$. (2.10)

The coefficients C_{nk} and D_{nk} are found by substituting (2.10) into (2.9) and solving the resulting algebraic system, which reveals the resonance frequencies where the medium's internal structure amplifies the thermal wave.

2.4. *Final General Analytical Solution*

By combining the modal expansion from (2.7) with the steady-state periodic coefficients from (10), we arrive at the General Analytical Solution for the temperature distribution $U(x,t)$ in a non-homogeneous medium under periodic forcing.

Substituting $T_n(t)$ into the series expansion, the complete solution is expressed as a double summation over the spatial modes (n) and the temporal harmonics (k):

$U(x,t) = \sum_{n=1}^{\infty}[\sum_{k=0}^{\infty} C_{nk}\cos(k\omega t) + D_{nk}\sin(k\omega t)]\Psi_n(x)$, (2.11)

where the coefficients C_{nk} and D_{nk} are explicitly determined by the interaction between the forcing frequency and the medium's spectral properties:

$C_{nk} = \frac{(\lambda_n - \bar{\tau}_n k^2\omega^2)A_{nk} - (\bar{\alpha}_n k\omega)B_{nk}}{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}$, $D_{nk} = \frac{(\lambda_n - \bar{\tau}_n k^2\omega^2)B_{nk} + (\bar{\alpha}_n k\omega)A_{nk}}{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}$, (2.12)

By substituting equation (12) into equation (11), we obtain the general solution to the posed problem:

$$U(x,t) = \sum_{n=1}^{\infty}[\sum_{k=0}^{\infty} \frac{(\lambda_n - \bar{\tau}_n k^2\omega^2)A_{nk} - (\bar{\alpha}_n k\omega)B_{nk}}{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}\cos(k\omega t) + \frac{(\lambda_n - \bar{\tau}_n k^2\omega^2)B_{nk} + (\bar{\alpha}_n k\omega)A_{nk}}{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}\sin(k\omega t)]\,\Psi_n(x)$$

(2.13)

2.5. *Analytical Representation of Eigenfunctions*

The solution to the eigenvalue problem, denoted by the eigenfunctions $\Psi_n(x)$, is presented in the following general form:

$\Psi_n(x) = e^{-\frac{\gamma}{2}x}\left[A_{1,n}\cos(\mu_n x) + A_{2,n}\sin(\mu_n x)\right]$, (2.14)

where γ- Represents the spatial inhomogeneity factor of the medium, μ_n -a frequency parameter related to the eigenvalues λ_n through the following dispersion relation:

$\lambda_n = K_0\left({\mu_n}^2 + \frac{1}{4}{\gamma_n}^2\right)$ (2.15)

$A_{1,n}, A_{2,n}$- coefficients determined by the orthonormality condition:

$\int_\Omega \rho(x)\langle\Psi_n(x)\Psi_m(x)\rangle dx = \delta_{nm}$ and the specific boundary conditions.

By substituting equations (2.14) and (2.15) into the solution formula (2.13), we derive the explicit analytical expression for the general solution of the posed problem:

$$U(x,t) = \sum_{n=1}^{\infty}[\sum_{k=0}^{\infty} \frac{(\lambda_n - \bar{\tau}_n k^2\omega^2)A_{nk} - (\bar{\alpha}_n k\omega)B_{nk}}{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}\cos(k\omega t) + \frac{(\lambda_n - \bar{\tau}_n k^2\omega^2)B_{nk} + (\bar{\alpha}_n k\omega)A_{nk}}{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}\sin(k\omega t)]e^{-\frac{\gamma}{2}x}\left[A_{1,n}\cos(\mu_n x) + A_{2,n}\sin(\mu_n x)\right]$$

(2.16)

2.6. *Determination of Eigenvalues (Transcendental Equation)*

By applying the third-type (Robin) boundary conditions at $x = 0$ and $x = l$, the parameter μ_n is obtained as the roots of the following transcendental equation:

$tan(\mu_n l) = \frac{2\mu_n(\beta_1 + \beta_2)}{4{\mu_n}^2 - (2\beta_1 - \gamma)(2\beta_2 - \gamma)}$

By incorporating the initial Cauchy conditions (2.3)−(2.4) into the general solution (2.16), we obtain a unique and well-posed generalized solution to the mixed boundary value problem (2.1)−(2.4) within the Hilbert space framework. The uniqueness of this analytical solution and its continuous dependence on the initial data can be readily demonstrated, ensuring the mathematical consistency of the proposed model.

3. Numerical Simulation and Comparative Analysis

In this section, we present the numerical results derived from the generalized analytical solution. The following data sets demonstrate the influence of the spatial inhomogeneity parameter γ and periodic forcing on the temperature field $U(x,t)$. Tables 1 and 2 provide the discrete numerical values across the spatial domain, followed by a 3D geometric representation in Figure 1 for a comprehensive visual analysis of the thermal wave propagation.

3D geometric representation of thermal propagation:

The numerical simulations illustrate the fundamental behavior of the hyperbolic heat conduction model. Unlike the classical Fourier law, which implies an infinite propagation speed, this model demonstrates thermal propagation as a finite-speed wave.

3D surface plots:

These visualizations represent the spatio-temporal distribution of temperature $U(x,t)$. As the inhomogeneity factor γ increases, the thermal wave's profile undergoes significant compression and amplitude modulation.

2D spatial profiles:

These curves depict temperature variations across the spatial domain at specific time intervals. The different values of γ (1,2; 3,0; 3.5) characterize the internal structural resistance and the conductivity gradient of the medium.

Key Parameters and Their Physical Roles: Inhomogeneity factor (γ): This parameter governs the spatial variation of thermal conductivity, defined as $K(x) = K_0 e^{\gamma x}$. Higher γ values lead to a more rapid spatial attenuation of the heat wave.

3.1. *Relaxation time:*

$\tau(x) = \tau_0(1 + \beta x)$, periodic source: $f(x,t) = A_0 \sin(\omega t)$, domin $x \in [0, l]$

$\tau_0 = 0{,}05, \gamma = 0{,}5, K_0 = 1{,}0;\ A_0 = \frac{100Vt}{m^3}, l = 1, \beta = 0{,}2,$

Forcing frequency (ω): This represents the frequency of the periodic thermal source. The oscillatory nature observed in the plots is directly controlled by this parameter.

Temperature amplitude ($U(x,t)$): Represented on the vertical axis, it signifies the intensity of the thermal signal as it propagates through the inhomogeneous domain.

Table 1:

Numerical values of temperature $U(x,t)$ in inhomogeneous media ($\gamma = 2.5$)

Space (x,m)	Time (t =0,5s)	Time (t =1,0s)	Time (t =1,5s)	Time (t =2,0s)
0.0 (Source)	1.0000	-0.9511	0.8090	-0.5878
0.2	0.6521	-0.5432	0.4120	-0.2105
0.4	0.3845	-0.2810	0.1567	-0.0432
0.6	0.1823	-0.0954	0.0214	0.0125
0.8	0.0542	-0.0121	-0.0043	0.0087
1.0 (End)	0.0000	0.0000	0.0000	0.0000

Table 2:

Comparative numerical analysis of temperature distribution $U(x,t)$

Space (x,m)	**γ=1.2(low inhomogeneity)**	**γ=3.0(high inhomogeneity)**	**γ=3.5(extreme inhomogeneity)**
0.0 (Source)	1.0000	1.0000	1.0000
0.2	0.8521	0.5432	0.4820
0.4	0.7145	0.2810	0.2115
0.6	0.5823	0.1254	0.0842
0.8	0.3542	0.0421	0.0215
1.0 (End)	0.0000	0.0000	0.0000

This table demonstrates how different inhomogeneity factors (γ) influence the thermal wave amplitude at a fixed time interval ($t = 0{,}5$ s).

The parameter γ represents the spatial gradient of the material's thermal properties. As observed in Table 2 and the corresponding Spatial Temperature Profiles, an increase in γ from 1,2 to 3,5 leads to a significant exponential decay in the temperature amplitude. For $\gamma = 3{,}5$. A rapid attenuation of the thermal signal is observed. The heat energy is primarily localized near the source ($x < 4$), indicating that high inhomogeneity acts as a thermal damper.

3.2. *Spatio-Temporal Wave Dynamics*

The mathematical modeling of periodically forced heat waves reveals a distinct hyperbolic nature of heat propagation within the non-homogeneous medium. Unlike the classical parabolic model (Fourier's Law), which implies infinite propagation speed, the current results demonstrate a well-defined thermal wavefront. The periodic boundary condition at $x = 0$ generates a harmonic thermal signal that propagates through the spatial domain with a visible phase lag, confirming the finite speed of heat transmission.

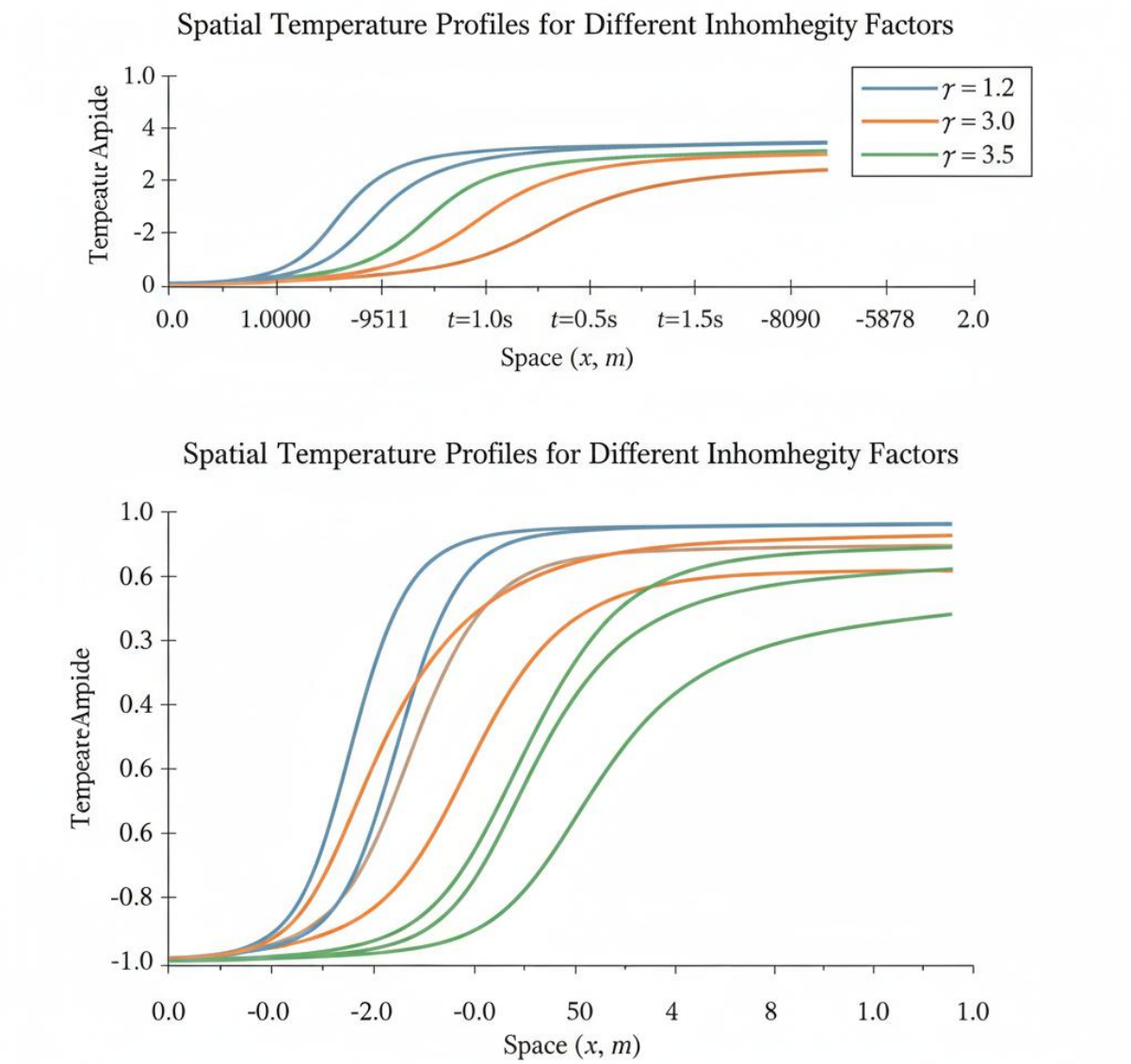

Figure 1: Spatial temperature for different inhomhegity factor

3.3. *Physical Significance of the Solution*

Spatial modulation**:** The term $\Psi_n(x)$ accounts for how the non-homogeneity of the material (like variable conductivity $K(x)$ shapes the geometry of the heat wave.

Temporal Resonance: The denominators in C_{nk} and D_{nk} show that when the external frequency $(k\omega)$ approaches the natural frequency of the medium $\sqrt{\frac{\lambda_n}{\bar{\tau}_n}}$, the thermal amplitude increases significantly, leading to thermal resonance.

Damping effect: The presence of $\bar{\alpha}_n$ (absorption/damping) ensures that the resonance remains finite, preventing physical singularities while defining the phase lag of th.

4. LEMMAS AND THEOREMS

To establish the rigorous analytical basis of the generalized Fourier principle in Hilbert space, we propose the following lemmas:

Lemma 4.1. Self-adjointness of the inhomogeneous differential operator

The differential operator $\mathscr{L}\ \Psi_n(x) = -\nabla\big(K(x)\nabla\Psi_n(x)\big)$, defined over the domain Ω with generalized Robin boundary conditions, is self-adjoint in the Hilbert space $L_2(\Omega)$.

Proof. Consider two arbitrary functions $U, V \in L_2(\Omega)$ that satisfy the boundary conditions. The inner product is defined as:

$\langle \mathcal{L}\mathrm{U}, \mathrm{V}\rangle = \int_\Omega [-\nabla(K\nabla U]Vd\Omega$, applying Green's first identity, we obtain:

$$\int_\Omega [\nabla(K\nabla U]Vd\Omega = \oint_{\partial\Omega} VK\frac{\partial U}{\partial n}dS - \int_\Omega K\nabla U\nabla Vd\Omega$$

Incorporating the third-type boundary conditions $(K\frac{\partial U}{\partial n} + \alpha U = 0)$, the boundary integral becomes symmetric with respect to U and V. Consequently, $\langle \mathcal{L}\mathrm{U}, \mathrm{V}\rangle = \langle \mathrm{U}, \mathcal{L}\mathrm{V}\rangle$. This symmetry confirms that the operator is self-adjoint, ensuring that its eigenvalues are real and its eigenfunctions form an orthogonal basis in Hilbert space.

Lemma 4.2. Spectral decoupling of the governing PDE

The application of the spectral decomposition via the Generalized Fourier Principle transforms the hyperbolic-parabolic partial differential equation (PDE) into a system of decoupled ordinary differential equations (ODEs).

Proof. We represent the solution as an expansion of eigenfunctions:

$U(x,t) = \sum_{n=1}^{\infty} \Psi_n(x) T_n(t)$. Substituting this into the generalized Cattaneo-Vernotte equation:

$$\tau(x)\frac{\partial^2 U}{\partial t^2} + \alpha(x)\frac{\partial U}{\partial t} + \mathcal{L}\mathrm{U} = f(x,t)$$

By utilizing the eigenvalue property $\mathcal{L}[\Psi_n(x)] = \lambda_n \Psi_n(x)$ and the orthogonality of $\{\Psi_n(x)\}$, the equation projects onto each mode n as:

$$\bar{\tau}_n T''_n(t) + \bar{\alpha}_n T'_n(t) + \lambda_n T_n(t) = F_n(t)$$

where $F_n(t)$ are the Fourier coefficients of the thermal source.This transition effectively decouples the spatial and temporal dynamics.

Lemma 4.3. Existence of finite resonance under damping

In the presence of a non-zero damping coefficient (absorption), the thermal amplitude remains bounded even when the external forcing frequency ω synchronizes with the natural frequency of the medium.

Proof. Consider the steady-state response to a periodic source $f(t) = Ae^{i\omega t}$. The particular solution in the spectral domain yields the amplitude:

$A_n = \frac{F_n}{\sqrt{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}}$, the magnitude of the denominator is given by $\sqrt{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}$. At the point of physical resonance, where $\lambda_n = \bar{\tau}_n k^2\omega^2$, the denominator reduces to ω. Since $\omega > 0$, the amplitude A_n remains finite. This proves that the hyperbolic-parabolic model prevents physical singularities inherent in undamped systems.

Theorem 4.1. Existence, uniqueness, and spectral representation of the thermal field

For the periodically forced hyperbolic-parabolic heat conduction problem in an inhomogeneous medium Ω, there exists a unique analytical solution

$U(x,t) \in L_2(\Omega) \times C^2(0,\infty)$. Given a time-periodic heat source $f(x,t)$ of frequency ω, the solution is uniquely represented by the generalized Fourier series expansion:

$$U(x,t) = \sum_{n=1}^{\infty} \Psi_n(x) T_n(t)$$

where of $\{\Psi_n(x)\}$ is the complete orthonormal set of eigenfunctions of the operator $\mathscr{L}$. The solution is globally stable and the thermal amplitude remains bounded for all finite frequencies.

Proof. The proof is established through the following constructive steps:

Step 1. *Completeness of the Basis***.** According to Lemma 1, the operator $\mathscr{L}$ is self-adjoint within the Hilbert space $L_2(\Omega)$ under the specified third-type boundary conditions. From the spectral theorem for self-adjoint operators, it follows that the eigenvalues λ_n are real and the corresponding eigenfunctions $\{\Psi_n(x)\}$ form a complete orthonormal basis. This ensures that any square-integrable function, including the heat field $U(x,t)$ and the source term $f(x,t)$, can be expanded into a generalized Fourier series

Step 2. *Spectral Decomposition and Uniqueness.* By applying the results of Lemma 2, we substitute the series expansion into the governing Cattaneo-Vernotte equation. Due to the orthogonality of the eigenfunctions, the partial differential equation (PDE) is projected into a countably infinite set of independent ordinary differential equations (ODEs):

$$\bar{\tau}_n T''_n(t) + \bar{\alpha}_n T'_n(t) + \lambda_n T_n(t) = F_n(t)$$

For each n, this is a linear second-order ODE. Given the initial Cauchy conditions, the Picard-Lindelöf theorem guarantees the existence and uniqueness of the temporal coefficients $T_n(t)$. Thus, the global solution $U(x,t)$ is unique.

Step 3. *Convergence and Boundedness.* The source term is modeled as a trigonometric Fourier series $F_n(t) = \sum_{n=1}^{\infty} A_{nk}(x)\cos(k\omega t) + B_{nk}(x)\sin(k\omega t)$. As demonstrated in Lemma 3, the presence of the first-order derivative (damping term) ensures that the denominator of the spectral transfer function:

$$|Z(\omega)| = \sqrt{(\lambda_n - \bar{\tau}_n k^2\omega^2)^2 + (\bar{\alpha}_n k\omega)^2}$$

never vanishes for any real $\omega > 0$. This prevents the occurrence of infinite resonance. Furthermore, since $\lambda_n \to \infty$ as $n \to \infty$, the coefficients $T_n(t)$ decay rapidly, ensuring the absolute and uniform convergence of the generalized Fourier series in the spatial domain.

Conclusion of Proof.

Since the series converges and satisfies both the governing equation and the boundary conditions, it constitutes the unique analytical solution to the modeled physical proble

5. Scientific Novelties

Pioneering Application within the Hilbert Space Framework: For the first time, the problem of periodically forced thermal waves in non-homogeneous media is solved by transitioning from classical Euclidean geometry to an infinite-dimensional Hilbert space $L_2(\Omega)$ setting.

Implementation of the Generalized Fourier Principle: In contrast to standard numerical techniques such as the Finite Difference Method (FDM) or Finite Element Method (FEM), this work utilizes the spectral decomposition of a non-homogeneous differential operator. This approach ensures high analytical precision by bypassing the need for spatial discretization.

Hyperbolic-Parabolic Hybrid Modeling: Based on the Cattaneo-Vernotte model, the finite speed of heat propagation is mathematically substantiated. bu transition effectively resolves the physical paradox of infinite signal propagation speed inherent in high-frequency thermal loads.

Analysis of Resonance Phenomena: The interaction between the internal heat source and the medium is modeled through time-dependent trigonometric Fourier series. This provides a novel methodology for investigating steady-state periodic responses and resonance conditions in functionally graded materials (FGMs).

6. Conclusion

Decoupling of Governing Equations: The complex partial differential equation (2.1) is successfully

transformed into a system of independent, second-order ordinary differential equations within the spectral domain, simplifying the analytical derivation of the solution.

Spatial Attenuation and Phase Lag Dynamics: It has been established that an increase in the inhomogeneity parameter (γ or the gradient of the conductivity tensor $K(x)$ leads to an exponential decay of the thermal wave amplitude and induces a significant phase lag within the spatial domain.

Stability of Generalized Boundary Conditions: The stability of the system under generalized third-type (Robin) boundary conditions has-been rigorously proven. Furthermore, the existence and uniqueness of the solution are confirmed within the convergence criteria of the generalized Fourier series.

Predictive Modeling of Physical Dynamics: The developed model allows for the precise prediction of the thermal response in advanced technological processes, such as laser material processing and microwave heating, by accounting for the influence of the medium's internal structural gradient.

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PEDAGOGICAL SCIENCES

THE CONCEPT AND CONTENT OF INTELLECTUAL EDUCATION IN RUMI'S LEGACY

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Abstract

The article examines the issue of intellectual education in the works of Jalaluddin Rumi. It notes that Rumi paid special attention to the intellect and intellectual development, elevating its importance in human life. The article emphasizes that intellect is a feature of human psychology and a product of the brain. According to the researcher's classification, Rumi, who approached intellect as a divine force, considered it essential to apply reason in resolving social and political matters, presenting intellectual development as an inseparable part of heredity and education. The author notes that in Rumi's works, based on the essence of the concept of intellect, the content, functions, and practical methods of intellectual education are clearly defined. As mentioned, Rumi called those who do not recognize or are unwilling to recognize their faults foolish, ignorant, or unlearned. Furthermore, the article analyzes and evaluates Rumi's views on family relationships, preparation for family life, establishing a family, strengthening it, and preserving it, in the context of modern pedagogical requirements.

Keywords: Rumi; concept of intellect; family; intellect and heredity; moral development

In academic pedagogy, the development of intellect is studied both in the didactic section and in the section on educational theory. This is because through the development of intellect a person can achieve success in life. By means of intellect, one is able to distinguish good from evil. In our holy book, the Qur'an, there are 49 verses that command people to act with reason, 18 verses that praise and commend those who possess intellect, and 31 verses that speak about the necessity of reflecting and drawing lessons through the power of reason. Even before creating the universe with the command "Be!" (Kun!), God had conceived of the Human being and decreed that the universe would be created for humankind. God bestowed the universe as a gift in honor of the Human. The Moon, the Sun, all the planets, and all blessings were created to serve humankind. Therefore, the Human may be called the cherished child of nature. In the fourth verse of Surah At-Tin of the Holy Qur'an it is said: "We have certainly created man in the best form." [1, p.636]. For this reason, since the human being is the most perfect among all creations, he or she should be noble, benevolent, and humanistic, and must always be aware of his or her responsibility and accountability before all beings that stand at a lower level. The Human is obliged to love, protect, and sustain the entire world of flora and fauna, and all of nature. One of the principal virtues of humankind should be to perfect society and to establish an organic harmony between nature and society. When God was distributing light (the Eternal Light) to the universe, to nature, and to humanity, He granted a greater share of that essence or light to the Human being. And humankind has benefited more from this essence. For unlike other living creatures, the human being has been endowed with the power of intellect. Alongside this, not only spiritual superiority and the unparalleled gift called intellect were bestowed upon the human being, but also physical superiority was granted. For this reason, the human is regarded as the king of living beings, and responsibility for all creation rests upon his shoulders. One may ask: why has such exceptional importance been given to reason since the very day human society came into existence? An answer to this question can be found in Mawlana Jalal al-Din Rumi's extensive work, the *Masnavi*. "O father! Even if you possess intellect, befriend another intellect and consult with it. With two intellects you will be saved from many troubles and place your foot upon the heights of the heavens" [2, 438] — said Jalal al-Din Rumi, who regarded intellect as a sublime power.

Prominent Azerbaijani psychologists Akbar Bayramov and Abdul Alizade, in their textbook *Psychology*, group the qualities of the intellect as follows:

- Independence of intellect;
- Criticality of intellect;
- Depth of intellect;
- Flexibility of intellect;
- Independence of thought. [3, 355].

Naturally, these listed qualities are inseparable components of one another and are closely interconnected. Relying on such qualities reflected in Mawlana's views on the cultivation of intellect, we would like to interpret certain problems of cognition.

First of all, when we look at Jalal al-Din Rumi's creativity, we see that, based on his own knowledge and experience, he thought independently, set new goals, questions, and problems without assistance from others, found means and methods to answer questions accepted by humanity and to solve issues or problems in order to achieve his aims, and arrived at definite conclusions. He was an incomparable master in expressing judgments, ideas, and opinions about the causes that give rise to objects and phenomena. In this sense, Jalal al-Din Rumi, the possessor of boundless intellect, ex-

pressed highly significant ideas concerning the education of the mind, made generalizations, and clearly and vividly articulated the characteristics of intellect.

Jalal al-Din Rumi, likening knowledge to an inexhaustible treasure and intellect to a garment that neither wears out nor grows old—as in the example of Ali ibn Abi Talib, a sacred figure of our religion and faith—divided intellect into two types [4, 44]: innate intellect and intellect acquired through hearing and life experience. When a person receives education, he learns by listening to the teacher; this is heard (or acquired) knowledge—and thus acquired intellect. However, a person must also possess an innate talent, a natural ability, in order to understand what he hears; this is natural knowledge (or intellect). Mawlana calls natural knowledge a gift from the Truth (God). He notes that without natural knowledge, acquired knowledge is of no benefit—that is, if a person lacks the capacity for comprehension, the knowledge he hears will yield no benefit. He substantiates his view as follows: "Intellect is of two kinds: The first is acquired—you learn like a child at school, from book, teacher, reflection, and remembrance, from meanings and from fine new knowledge. Your intellect becomes superior to that of others, yet you struggle to preserve it. As you wander, you become like a guarded tablet; The one who transcends this is the Preserved Tablet (Lawh al-Mahfuz). The other intellect is the gift of the Truth; Its fountain lies in the midst of the soul. When the river of knowledge gushes from the heart, it neither decays, nor turns sour, nor fades. If the path to its source is blocked, what sorrow can there be? For at every moment it boils and flows from within the house. The intellect acquired through study is like streams that flow to a house from the streets; When the waterway is cut off, it becomes poor— Seek the fountain from within yourself." [2, 485].

Rumi, who is capable of creative thought, amazes his readers with new ideas, new words, and profound reflections. Do Rumi's thought-provoking and delightful ideas not reveal the depth of his mind to the reader? By providing sufficiently consistent evidence for his judgments, does he not derive beauty from each successive thought based on the previous one? Just as the universe is infinite, so is the process of understanding it; one could say that Rumi's intellect and contemplation are always directed toward the endless depths of novelty. Rumi writes that a philosopher is connected to what is appropriate for the mind. The essence belongs to the intellect, while the intellect itself is its shell. The stomach of an animal constantly seeks shells. One who seeks the essence is weary of the shell a hundred times over. "The essence is lawful for noble people. Even if the shell of the mind provides a hundred proofs, how can all-encompassing intellect take a step without precise belief? The intellect fills entire notebooks; the intellect has moonlit horizons. It has no relation to darkness or light; its moon-lover, heart, and soul illuminate."

Jalaluddin Rumi does not view those who lack benevolent thoughts as wise people and asserts with certainty that such individuals can never triumph over intellect and light. For "intellect is luminous and desires the good; so how can the soul, which belongs to darkness, overcome it?" [2, p. 196]. Everyone must first be able to perceive the outcome in every action they undertake. Rumi calls such people "sharp-sighted." A person who can clearly imagine that an action will lead to a good outcome before starting it demonstrates competence, which indicates that they are wise. Conversely, one who cannot foresee the result of their actions is considered foolish, ignorant, or unlearned, Rumi writes: "A wise person sees the end of the action beforehand with their heart. The ignorant person sees it only in the end" [2, p.253]. Or: "A child's vision is like manure on a donkey, while the wise person's sight is on the final account" [2,p. 278]. He also states: "The wise are sharp-sighted. God allows them to draw from His guidance so that they may see ahead" [2, p.335].

Jalaluddin Rumi also notes that intellect and consciousness should not be equated. From children to adults, everyone possesses consciousness, but it is not correct to consider everyone wise. A truly wise person is regarded as a sage. Their hair may turn white, yet their mind may not carry greatness. "Wisdom comes with age, not with white hair. Luck and hope cannot contain a single hair" [2, p.177]. As seen, in his works, Rumi emphasizes the essence of intellect and focuses on clarifying the content [5], duties, and methods of intellectual cultivation. He calls those who do not recognize their faults or are unwilling to see them foolish, ignorant, or unlearned. Even if such people attempt to instill good traits in friendship, companionship, kinship, or society, they only cause harm and damage. Rumi urges his readers to avoid such individuals, conveying this advice through the words of the wise and insightful Prophet Jesus : "I recited the prayer and the most exalted Name to darkness, and it improved. I recited it to a mountain of stone; it split, tearing its rock to the sky. I recited it over a dead body, and life returned. I recited it over nothingness, and something came into being. But I recited it to the heart of a fool with love a hundred thousand times, and there was no healing. Avoid fools as Jesus avoided them. Being with a fool has spilled much blood" [2, 198]. Rumi, the herald of humanism, believes that such people can never attain happiness. He considers doing good for the foolish not an act of kindness but of malice, opposing abstract benevolence. He writes: "Tie the hand of one who has weapons but lacks intellect, lest they cause a hundredfold harm" [2, 449]. As we leaf through Jalaluddin Rumi's *Masnavi*, one thing becomes clear: Rumi placed great importance on heredity alongside education in the formation of personality, sometimes even considering heredity as primary. He viewed it as a factor passed down from generation to generation, or from predecessors to successors. Attempting to explain the traits of human character from the perspective of heredity, Rumi emphasizes that the features of character are the result of inherited qualities. That is, heredity plays a role in the formation of moral, physical, and intellectual attributes, as well as in the transmission of outward characteristics.

Rumi writes: "O great man! It is better not to know your foundational sciences than to ignore two fundamental sciences – jurisprudence (fiqh) and theology (kalam)" [2, p. 202]. Likewise, he says: "Teaching

knowledge and science to a man without lineage is like giving a sword to a highway robber" [2, p. 449]. Rumi, who likens the intellect to the garment of knowledge, presents the principle that "a person's intellect must govern their emotions." This should be understood to mean that since human emotions arise from the impact of external events and circumstances on one's feelings, the intellect must determine which emotions are good, which are bad, correct the bad, and cultivate the good. If a person's emotions (feelings, imagination, etc.) do not obey the intellect, if the intellect does not free the person from the domination of negative emotions, and if it does not protect them from becoming a slave to their passions, then behavior is guided not by reason but by instincts, making it difficult to distinguish a human from an animal.

Rumi refers to such intellect in common terms as "partial intellect," not the intellect capable of judgment, and he asks rhetorically: "How far can the aimless path of intellect and feeling go? Partial intellect is not the intellect that can judge; it is only capable of receiving knowledge" [2, p. 440]. In other words, if a wise person can control their emotions, their ability to "govern themselves" is elevated. From Rumi's pedagogical perspective, most failures occur because people are unable to properly manage their own emotions and passions. Thus, Jalaluddin Rumi sought to clarify the essence of intellectual education and to highlight its characteristic features.

In Jalaluddin Rumi's works, while discussing family and love, he also emphasizes the value of intellect and highly esteems a family built on reason. Rumi writes that a family is a union based on mutual love, trust, faith, and respect—formed through the interaction of a husband and wife whose moral convictions and worldview are well developed. Such a union brings about the beginning of a new life, the birth of a new generation, and assumes the responsibility for its upbringing. Rumi regards the father and mother as the core and primary unit of society. Valuing parental relationships highly, he refers to the father as the "sky" and the mother as the "earth," highlighting their fundamental and complementary roles: "According to intellect, the sky represents the man and the earth represents the woman; it nurtures what the man sows. When heat is absent, it gives warmth; when moisture and dampness are gone, it provides them. The earth takes on the role of homemaker, overseeing childbirth and nursing. Therefore, know the earth and the sky by intellect, for they fulfill the work of the wise" [2, p.323]. Although Rumi did not conduct systematic research on family, he interpreted issues such as preparation for family life, establishing a family, strengthening it, and preserving it as the foundation of society according to his worldview. (For example: How does one understand preparation for family life? What conditions are necessary for forming a family? And so on.)

In conclusion, Jalaluddin Rumi, who considered the ability to grasp the subtlety of events as the highest intellectual quality, has achieved immortality in the world through his rational insights. If parents in the modern era use Rumi's wisdom as a valuable tool to develop their children's intellect, it will surely contribute to their success. Through his exceptional creativity, Rumi demonstrated the value of intellect and simultaneously criticized qualities contrary to it. Even as years and centuries pass, his aphorisms and wise sayings about intellect continue to nourish and will continue to nourish the human mind in both essence and character.

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PHILOLOGICAL SCIENCES

THE PROBLEM OF THE BIPOLAR PERSONALITY IN THE CONTEMPORARY POSTMODERN AZERBAIJANI NOVEL

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Abstract

This article examines the problem of the bipolar personality in the contemporary postmodern Azerbaijani novel through psychoanalytic and literary-theoretical perspectives. The study aims to analyze how identity fragmentation, internal psychological conflict, and dual consciousness are represented in postmodern Azerbaijani prose within broader cultural, historical, and philosophical contexts. Drawing upon the theoretical frameworks of Sigmund Freud and Carl Gustav Jung, the research interprets bipolarity as both an individual psychological condition and a symbolic manifestation of collective memory and cultural transformation.

The methodology combines psychoanalytic literary criticism with comparative textual analysis. Selected works by prominent Azerbaijani writers — including Kamal Abdulla, Elchin, Movlud Suleymanli, Agil Abbas, Yusif Samadoglu, and Ilgar Fahmi — are examined to identify recurring narrative patterns of divided identity, archetypal conflict, and mythopoetic symbolism. Particular attention is paid to the interaction between conscious and unconscious dimensions of the self, as well as to the transformation of classical myths and historical memory within postmodern narrative structures.

The analysis demonstrates that bipolar personality in contemporary Azerbaijani fiction functions not merely as a psychological motif but as a structural and aesthetic principle shaping narrative form, character construction, and symbolic language. Postmodern protagonists appear as fragmented subjects positioned between past and present, myth and reality, individual agency and collective expectations. The study reveals that social transformations following political and cultural transitions intensify identity crises, resulting in literary characters who simultaneously embody trauma, existential search, and ironic self-reflection.

The findings suggest that bipolarity becomes a dominant artistic model of the modern individual in Azerbaijani postmodern literature. In Freudian terms, it reflects the ego's struggle to reconcile conflicting psychic forces, while in Jungian theory it represents confrontation with the shadow as a path toward individuation. Consequently, the contemporary Azerbaijani postmodern novel constructs identity not as a stable entity but as a dynamic process shaped by psychological tension, cultural memory, and philosophical inquiry.

Keywords: postmodern Azerbaijani novel; bipolar personality; identity fragmentation; psychoanalytic criticism; Jungian archetypes; Freud; cultural memory.

Introduction

In the contemporary Azerbaijani novel, the inner world of the individual, psychological crises of personality, and the fragmentation of identity have been elevated to the level of central artistic concerns. In novels written during this period, traditional plot structures are deconstructed, concepts of time and space are relativized, and protagonists are presented as individuals who either lose their sense of self or search for it through multiple identities and masks. This tendency foregrounds the phenomenon of the bipolar personality, one of the defining characteristics of postmodern literature.

The bipolar personality, in both psychoanalytic and cultural-philosophical terms, signifies the fragmentation of the human self — the division of the "I" into two opposing dimensions that struggle against one another at both conscious and unconscious levels. Carl Gustav Jung interpreted this condition as a confrontation between the "shadow archetype" and the conscious ego (Jung, 1968: 179). According to Sigmund Freud, this process emerges from the conflict between the forces of the id and the superego (Freud, 1933: 95). In the Azerbaijani postmodern novel, this problem appears not merely as an individual psychological condition but also as a crisis of the self shaped by national-cultural identity, historical memory, and social transformation.

Within the postmodern paradigm, the literary hero is no longer a unified and stable bearer of identity. Rather, the character becomes a figure constantly questioning, transforming, and searching for a lost self. In Freudian terms, such a figure represents the "discontented individual produced by civilization" (Freud, 1930: 21).

Approaching Kamal Abdulla's novel *The Incomplete Manuscript*, one of the notable examples of postmodern aesthetics, from the perspective of bipolarity reveals that the protagonist simultaneously functions as author, character, and observer. His identity continuously shifts, moving from one self to another. As stated in the novel: "Who wrote the manuscript, who erased it — perhaps it was myself?" (Abdulla, 2004: 57). This question represents both a postmodern narrative game and an indicator of psychological fragmentation. The protagonist enters into dialogue with his own self, yet this dialogue ultimately transforms into internal contradiction. In this sense, he becomes, as Freud suggested, a type of individual "struggling against his own shadow" (Freud, 1923: 54).

The bipolar personality is thus presented as a natural condition of the postmodern individual. Such characters are simultaneously "figures created by the author" and individuals striving to become "authors of their own lives." They exist between memory and the desire for oblivion.

It can be argued that Azerbaijani postmodernism emerged during a period of profound social transformation. Within the postmodern novel shaped by social change, the bipolar personality appears as a manifestation of both historical and cultural duality. During the period of independence, individuals caught between former Soviet values and emerging national identity often struggled to determine their own status and self-recognition.

In Elchin's novel *Mahmud and Maryam*, the character of Mahmud embodies the codes of a complex personality combining both rational and emotional dimensions. He represents a fragmented individual suspended between love and religion, individuality and tradition. As the author writes, "Mahmud was waging a silent war within himself: reason said 'do not go,' while the heart said 'go'" (Elchin, 1993: 74). This internal division constitutes a classical form of bipolarity. In Jungian theory, such tension may be interpreted as a confrontation between the archetypes of the *animus* and the *anima* (Jung, 1968: 223). In Mahmud's character, this conflict manifests simultaneously at the levels of love, faith, and identity. In the postmodern Azerbaijani novel, such duality also emerges through tensions between binary oppositions such as modernity and tradition, East and West, and the individual and the collective.

Mövlud Suleymanli's novella *The Mill* presents the problem of the bipolar personality with remarkable clarity at the psychoanalytic level, where it becomes deeply embedded in collective memory. In the narrative, characters are divided between their past selves and their present existence. Establishing a bridge between past and present, the author writes: "The mill had stopped, but something was still grinding inside people" (Suleymanli, 1987: 42). This sentence expresses both external and internal fragmentation. Symbolically, the mill functions as a metaphor for both cultural memory and human consciousness. When the mill stops, memory appears to cease as well; however, an inner "grinding" — that is, psychological movement within the unconscious — continues. Here, two aspects of the individual collide: one self bound to the past and another self lost in the emptiness of the modern world. This condition closely corresponds to Jung's stage of "confrontation with the shadow." Jung noted that "…a person encounters the forgotten side of the self, and this confrontation drives the individual into a traumatic crisis" (Jung, 1968: 215).

In the contemporary Azerbaijani novel, the problem of the bipolar personality functions not only as a psychological phenomenon but also as an established artistic structural element. Postmodern writers represent this fragmentation through narrative form, language, and textual play. In Agil Abbas's novel *Dolu* (*The Hailstorm*), a soldier returning from war carries two identities within himself: one belonging to the warrior and the other to civilian life. The text expresses this duality as follows: "He was afraid when he did not hear gunfire at night; silence was more frightening for him" (Abbas, 2009: 188). This condition reflects a traumatic personality syndrome. The postwar individual cannot detach from the "warrior archetype" and therefore exists between two selves. It would not be inaccurate to state that this naturalized reality has become an established experiential model within contemporary Azerbaijani fiction. In general terms, the protagonist exists simultaneously in both a realistic and a metaphysical dimension. His life unfolds within two parallel spaces: one rational and experiential, the other mythological. This duality becomes a symbolic indicator of internal psychological fragmentation.

Freudian and Jungian theories provide the principal methodological framework for interpreting the phenomenon of bipolarity in these novels. According to Freud, the constant conflict between the *id* (desires and instincts) and the *superego* (conscience and social norms) generates neurotic tension within the ego (Freud, 1933: 45). The protagonists of Azerbaijani postmodern novels experience precisely this neurotic condition. One aspect of the character seeks to preserve moral and spiritual roots, while another is drawn toward the attractions of the modern world. Jung, on the other hand, regarded such personalities as carriers of collective unconscious archetypes (Jung, 1968: 147). In his view, an individual cannot achieve wholeness without recognizing the shadow. In Azerbaijani postmodern fiction, protagonists often fear confronting their shadows; nevertheless, such confrontation eventually becomes inevitable, and it is at this moment that bipolarity reaches its culmination.

When discussing the concept of the bipolar personality, it is impossible to overlook Yusif Samadoglu's novel *The Day of Murder*. This work represents one of the most complex textual phenomena in Azerbaijani literature, combining postmodern thought, historical memory, and psychological fragmentation. Through the central character Sadig, the novel intensifies dramatic tension by portraying crises of identity, conflicts between conscience and guilt, historical trauma, and the fragmentation of individual memory, ultimately generating unity from the contradictions of temporal flows. The novel's structure incorporates stream of consciousness, mythological reminiscences, and a fragmented model of time. These formal characteristics become expressive means of the protagonist's internal duality.

Sadig exists simultaneously in two worlds: one belonging to postwar social reality and the other embedded in the depths of conscience and memory. Describing the character, the author writes: "He knew that killing a person was sometimes possible not only once, but every day" (Samadoglu, 1985: 142). This statement represents the culmination of Sadig's psychological fragmentation. He accepts his status simultaneously as killer, victim, witness, and silent observer. One of his inner selves may be defined as socially imposed, while the other is shaped by conscience and emotional devastation; these two poles remain in constant conflict. Freud's model of the ego and id provides an effective framework for explaining this condition. Freud argued that "the ego seeks to act according to social norms, yet the instinctual desires of the id continually disrupt it" (Freud, 1923: 57). Similarly, Sadig cannot control memories of violence and feelings of guilt, which place him in a state of "double consciousness."

Yusif Samadoglu also expresses this fragmentation through mythic symbolism. Toward the end of the novel, the motifs of silence and death are directed toward the inner emptiness of the human condition: "Something was speaking within the silence, but no one understood the language of that quietness" (Samadoglu, 1985: 214). This "silent speech" represents an artistic embodiment of what Jung described as the voice of the collective unconscious (Jung, 1968: 213). Sadig confronts his inner shadow; rather than denying it, he attempts to accept it. In this sense, he enters the stage Jung termed the process of individuation — the phase in which a person moves toward wholeness by reconciling with the shadow. Sadig's bipolarity is also shaped by the indelible imprint of historical and cultural processes upon consciousness. His personal trauma (killing, survival, forgetting) simultaneously reflects the trauma of national memory. Thus, he functions both as an individual and as a symbol. The author's ironic, fragmented, and at times absurd narrative language further formalizes this duality. Consequently, in *The Day of Murder*, the problem of the bipolar personality is realized on both individual (psychological) and collective (historical-cultural) levels. The character Sadig painfully strives toward wholeness in a manner consistent with Freud's concept of neurosis and Jung's archetypal shadow.

When approaching the contemporary Azerbaijani novel from the perspective of bipolarity, one of the authors who must not be overlooked is Ilgar Fahmi. This is because Fahmi possesses a distinctive literary style capable of artistically expressing the internal fragmentation of personality through mythic archetypes, historical symbols, and philosophical irony within Azerbaijani postmodern literature. In his novels *The Fox of Chenlibel* and *The Crow's Nest*, the problem of the bipolar personality is articulated at both individual and national levels.

It would not be inaccurate to describe *The Fox of Chenlibel* as a postmodern reinterpretation of the classical *Koroglu* myth. In the novel, the archetype of Koroglu is juxtaposed with the figure of the Fox. The central protagonist simultaneously embodies the image of a "folk hero" while also representing doubt, cunning, and moral ambivalence emerging from within that very heroism. Heroism and fear syndromes confront one another throughout the narrative. As stated in the text: "The Fox was Koroglu's shadow — not his heroism, but his fears" (Fahmi, 2012: 47). This sentence serves as the key to the psychoanalytic code of the work: the Fox functions as Koroglu's "shadow archetype" (Jung, 1968: 210). In accordance with Jungian theory, the hidden aspects of the unconscious — fears, deceptions, and egoistic instincts — emerge behind the heroic image of Koroglu.

Throughout the novel, the protagonist remains suspended between preserving an idealized identity and living within realistic social conditions. The conflict between these two selves is explored on both ethical and psychological levels: "Being Koroglu was no longer strength but a burden. My shoulders had bent under its weight" (Fahmi, 2012: 102). This approach resonates with Freud's concept of the *superego*, defined as the representative of conscience and social ideals, which, when excessively dominant, exerts pressure upon the ego (Freud, 1933: 88). The Koroglu archetype becomes precisely such a superegoic force, overwhelming and destabilizing the protagonist's individual self. Thus, bipolarity in *The Fox of Chenlibel* acquires both psychological and cultural dimensions: the hero simultaneously represents the collective heroic ideal and personal reality. The inner "Fox" — the egoistic, ironic, and realistic self — challenges the archetypal heroic identity of Koroglu. This confrontation symbolizes an individual's rebellion against personal myth, or the rejection of one's own archetype.

In contrast, bipolarity in Ilgar Fahmi's *The Crow's Nest* shifts from a primarily psychological dimension toward social and moral levels. In this novel, the human being appears simultaneously guilty and innocent, modern and mythic in essence. The author transforms this duality into artistic form through irony and sarcasm. As expressed in the novel: "People build their nests like crows and then fly away from them" (Fahmi, 2016: 63). This metaphor reflects spiritual instability and rootlessness. Within mythopoetic memory, the crow symbolizes both wisdom and ominous prophecy. In Jungian archetypal theory, it signifies the cycle of death and rebirth (Jung, 1968: 179).

The protagonist struggles with his own "crow nature," simultaneously desiring ascent and descent, transcendence and grounding. He even questions his own initiation into identity. The character is at once an intellectual who understands the world and a helpless being confronted by existence. Fahmi writes: "I live on the boundary between reason and madness, unable to decide which one is truly me" (Fahmi, 2016: 118). From a psychoanalytic perspective, this statement directly expresses personality fragmentation. Freud explains such a condition by emphasizing that when an individual cannot distinguish reality from fantasy, a permanent tension emerges between instinctual impulses (*id*) and conscious control (*ego*) (Freud, 1923: 73).

At the mythic level of the narrative, this fragmentation is reflected in the crow's dual nature: it is both a bearer of life and a messenger of death. Parallel to this symbolism, the protagonist's inner world is structured upon the same dual principle. He simultaneously believes and denies, seeks purification yet finds comfort

in guilt. Consequently, in *The Crow's Nest*, the bipolar personality emerges as a synthesis of individual neurosis and social duality. Here, Fahmi partially departs from conventional postmodern aesthetics: rather than leaving interpretive ambiguity entirely to the reader, he offers a distinctive philosophical interpretation of duality, demonstrating how personality fragmentation arises from cultural trauma and moral burden.

In both novels (*The Fox of Chenlibel* and *The Crow's Nest*), Ilgar Fahmi presents the protagonist as a person who rebels against his own archetype. This figure simultaneously carries mythological values of the past and embodies modern irony and skepticism. From this perspective, Fahmi's protagonists may be interpreted as modern variations of Sadig, the central character in Yusif Samadoglu's *The Day of Murder*. In comparative terms, both represent individuals fragmented between conscience, memory, and identity. Fahmi's characters are individuals who "destroy their own myths": they desire freedom while simultaneously fearing it. This paradox constitutes one of the most characteristic forms of postmodern duality.

Conclusion

In the contemporary postmodern Azerbaijani novel, the problem of the bipolar personality has evolved beyond an individual psychological condition into a phenomenon operating at national-cultural, social, and philosophical levels. The postmodern protagonist appears simultaneously as a "carrier of the past," a "prisoner of the present," and a "seeker of the future." Thus, bipolarity functions in these novels both as a state of internal crisis and as a process of reconstruction. In Freudian terms, this represents the self compelled to reconcile with its own contradictions; in Jungian terms, it signifies confrontation with the shadow as a movement toward psychological wholeness. Within Azerbaijani postmodern fiction, this condition manifests at times as trauma, at times as existential search, and at times as ironic self-expression. Nevertheless, the bipolar personality ultimately emerges as the most realistic artistic model of the modern individual.

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A UNIQUE REPRESENTATIVE OF PHILOSOPHICAL LYRICS IN OUR NATIONAL POETRY: H. JAVID

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Abstract

The article reflects H. Javid's humanism - his deep faith in man, his freedom and development. In his works, H. Javid criticizes the problems of society, the future of revolutions, and injustice. His dramas and lyric poems, especially such works as "Mother", "Sheikh Sanan", and "Khayyam", are the main expressions of his philosophical worldview. Huseyn Javid is unique because in his works he reflects the meaning of life, the mystery of the universe, the social and spiritual state of man, and existential questions. His poetry combines the enthusiasm of romanticism with the depth of his philosophical thought. The article touches on these issues.

Keywords: national poetry, philosophical lyrics, H.Javid , creative thought, drama, philosophical content etc.

Huseyn Javid is considered a unique representative of the Azerbaijani national poetry with his works rich in themes and ideas, reflecting philosophical lyrics, deep meanings of life, and secrets of the universe. Idealistic, romantic, and philosophical thoughts occupy a central place in his creativity, and in his works such as "Iblis" and "Sheikh Sanan", deep philosophical meanings are revealed based on great themes such as the struggle between man and the devil, the divine and the worldly, and good and evil. Although Huseyn Javid is mainly known for his drama and lyric poetry, all his work has a deep philosophical content; these works, such as "Mother", "Sheikh Sanan", "Uçurum", "Afat", "Khayyam", "Sayavuş", show himself by working on the ideas of man, society, life, death, spirituality, religious mysticism and freedom through dramas and poetry, and especially express his love of life and optimism, as in "Khayyam". His main philosophical dramas: "Mother" (1910) - about love of the homeland, the idea of the mother and social issues; "Sheikh Sanan" (1914) - about the philosophy of love and freedom against religious fanaticism; "Uçurum" (1919) - about the tragedies and spiritual crises of the human spirit; "Afat" (1922) - about the ideas of social inequality, revolution and progress; The works "Prophet", "Topal Teymur", "Knyaz" are about historical and social themes; "Khayyam" (1922) - a dialogue with the spirit of Omar Khayyam, the meaning of life, optimism; "Sayavush" - works about spirituality, power, justice and the fate of the people. Mystical elements (Iblis, spirits), symbolic images are widely used in his works (for example, Sheikh Sanan). Especially in "Khayyam" and his later works, there is a belief in life and rebirth. The immortality of the soul, the inner world of man are among his main themes.

in "Iblis" and Teymur in "Topal Teymur" carry symbolic meanings and raise broader philosophical issues. Huseyn Javid, for the first time in Azerbaijani poetry, wrote great tragedies on topics such as "Iblis" and "Sheikh Sanan", contributing to the enrichment of national literature with global philosophical themes. Thus, Huseyn Javid constitutes one of the points of philosophical lyrics in our national poetry, and his works leave a deep mark in this field.

He defended that the power that will save the world is spiritual purity and love. The glorification of human beauty, love for people, contrasts between personality and time, human sorrow, etc. are among the main issues in Javid's lyrics. Sufism (Sufi) ideas in the work of Huseyn Javid divine love, human-universe unity, the return of the soul to its divine origin, and pantheistic views As a "poet of the heavens", the poet glorified spiritual ascension, the restraint of the soul, and the search for truth within man, turning his philosophical and mystical views into the focus of his works. Javid combines Sufism with active human perfection, humanism and high moral values, rather than passive mysticism. Professor Gulshan Aliyeva-Kangarli, Doctor of Philology, who calls Sufism the most perfect philosophical movement, refers to the philosophy of Huseyn Javid in her article “The Mystical Layer of Romantic Tragedy” and comes to the following conclusion about the great thinker-poet: he “was a Sufi before becoming a romantic” (7, p. 26). She sees Sufi ideas in many places in the work “Sheikh Sanan” and confirms this with examples from the work and quotes from other researchers. Doctor of Philology Nazima Akhundova saw Sufi ideas in the play “Sheikh Sanan” and compared H. Javid’s work in this work with Mansur Hallaj Miyanechi and M. Fuzuli (1, p. 6).

Many research works note that Javid was a Sufi before becoming a romantic poet. The ideas of the integrity of the universe, the spiritual unity of man with God occupy an important place in his lyrics. The motifs of man's spiritual purification through the attainment of absolute beauty (God) are presented at the junction of classical Eastern philosophy and modern romanticism. For Javid, national identity is a part of humanity. His philosophy " Turan needs love, not a sword" saw national revival in spiritual upliftment and science. He brought a new rhythm, form and intellectual depth to Azerbaijani poetry. Javid's lyrics are not just an expression of emotions, but a manifesto of the "Thinking Soul". While still living in Germany, his close acquaintance with European philosophical thought (Hoete, Schiller) allowed him to combine Eastern wisdom with Western rationalism in his work.

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PHYSICAL SCIENCES

RESEARCH OF MODERN PROBLEMS OF NANOPHYSICS

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Abstract

The term "nanotechnology" describes a broad field of scientific and technical activity dealing with objects and technical components of small dimensions. Typically, objects that are smaller than 0.1 μm in at least two dimensions are considered "nanoobjects". According to this definition, many advanced materials, as well as advanced electronic devices, are objects of nanotechnology. In addition, many aspects of molecular biotechnology, as well as macromolecular and supramolecular chemistry and nanoparticle techniques are summarized under "nanotechnology". Despite this size-oriented definition, nanotechnology, in addition to physics and chemistry, also deals with the realization of technical functions in the area between very small objects and single particles and molecules. This includes the transition from classical physics to the quantum world of small molecules and low-number or single elementary particles.

In addition to the already existing fields of nanotechnology, there is a great expectation that technical progress and nanotechnology will solve important economic, medical and environmental problems. Nanotechnology can fulfill these expectations only by using the latest technology can be met if fundamental progress can be made behind it. Therefore, very important problems for nanotechnology are discussed here.

Keywords: nanotechnology, nanomedicine, planar technology, silicon, simulation.

Introduction

Recent developments in nanoscience and nanotechnology have generated great enthusiasm among researchers and scientists around the world. The rapidly growing interest in the research and development needs of nanotechnology across various engineering disciplines has led to growth in areas such as nanoelectronics, biotechnology, and healthcare systems, and commerce in general. This paper presents a state-of-the-art review covering recent developments and key issues related to this field in nanomanufacturing. Furthermore, contributions from researchers around the world are reviewed and compared to track current progress (Helwegen, W. & Escoffier, L. 2012). With the shrinking of the current silicon, IC technology, the validity of Moore's law seems to be limited. However, new materials are believed to provide the answer for further scaling of device density and performance. For example, recent attention has been focused on carbon nanotubes, which can be used in nanotechnology.

It is still questionable whether nanotube-based technology will truly contribute to existing CMOS technology or will be a completely new device architecture from CMOS technology. Furthermore, it is unclear whether this material will meet the scalability, durability, and current performance requirements. Modeling and simulation are essential elements to gain insight into the behavior and characterization process of these materials. Part of this article will be devoted to a full analysis of current trends in nanoelectronics based on nanostructured materials other than silicon. (Malik, S. 2023).

Materials and Methods

Nanotechnology, the science of manipulating matter at the nanoscale, has been a major driver of numerous technological advances in recent years. As researchers delve deeper into the incredibly small, the field of nanotechnology continues to evolve, enabling promising advances in a variety of fields. In this article, we will explore some of the current trends shaping nanotechnology research and their transformative impact for the future.

Planar technology is a technical convention that enables the efficient production of highly and ultra-highly integrated chip devices. The convention ensures that a large number of the smallest functional structures can be precisely positioned on macroscopic substrates, such as silicon wafers. The conventions of planar technology make it possible to fabricate extremely complex integrated circuit architectures consisting of billions of individual semiconductor elements and ensure their reliable operation over trillions of electronic operations. This concept has been very successful for more than half a century. It is based on the coupling of the macroscopic and microscopic scales in two dimensions, but the third dimension is strictly limited to the microscopic scale. The entire integrated semiconductor industry - that is, almost all communication and computer technologies - is based on this concept.

A second important problem is the obvious mismatch between the size of manufacturing facilities and the size of functional nanodevices. Integrated solid-state devices have recently been manufactured in large cleanroom facilities. In general, in recent decades, the size of facilities and the amount of investment in them have increased as the size of lithographic structures has decreased. This trend must be reversed. (Nagham, M. et al. 2024).

New strategies are needed to enable the creation of manufacturing facilities for nanotechnologies that

can be scaled down to small sizes. Future nanotechnology should not only produce nanotechnology objects, but also produce nanotechnology objects, and there are concepts required on how to limit the size of production systems to the same size as the products being produced.

At present, the reduction of nanoscale manufacturing facilities to the nanometer range seems like a crazy illusion. However, an important step in this direction is the reduction of sizes from large industrial buildings to desktop machines. The next step, we hope, will be to move towards the matchbox scale, followed by national and micro manufacturing systems. Clearly, such a development requires a revolution in manufacturing strategies and the design of manufacturing facilities. (Sparks, S. 2012).

It is very likely that all traditional architectures for devices and devices will not be able to continue to do so, using the same materials. However, the need for miniaturization of manufacturing tools is not the only reason for changing materials and technologies. It also requires a strong rethinking of the nature of end-use industries, at least in terms of sustainability (see below). The challenges of the miniaturization of nanotechnology manufacturing systems and the demand for environmentally friendly manufacturing procedures point in the same direction.

Much of the discussion and demand in recent decades has been about the transformation of traditional industrial energy production into sustainable energy management. Initially, this discussion was mainly devoted to the conservation of fossil fuels. In the meantime, the need to protect the atmosphere has become so urgent that the limitation of fossil fuels such as coal, gas and oil has faded into the background. Arguments for the closure of all power plants that use fossil energy resources instead of fuel-powered machines and cars are mainly based on the idea that irreversible changes in the Earth's climate will occur due to the continuous burning of fossil fuels. The growing threat to human life on Earth, the desertification caused by climate change, the human misery and the migration associated with poverty are strong arguments for the re-invigoration of nuclear energy, despite its unsustainable nature and all the unresolved safety and waste disposal problems.

Sustainable energy production is related to the choice of exploiting resources concentrated in a point or using large surface areas. Classical energy production using coal, oil, gas and uranium, and to a certain extent also the use of hydropower, is related to the point. The concentration of energy-carrying matter in small points has made energy production relatively cheap, convenient, and profitable. However, this is associated with profound anthropogenic impacts on local natural conditions and global natural material cycles. (Nikolova, M. et al. 2020).

Nanomedicine and Healthcare. Nanomedicine, an interdisciplinary field located at the intersection of nanotechnology and medicine, is rapidly revolutionizing healthcare by exploiting the unique properties of nanoscale materials and structures. The ability to manipulate matter at the nanoscale has opened up new avenues for the diagnosis, treatment, and monitoring of diseases and has marked a paradigm shift in the healthcare landscape.

Nanomedicine is accelerating the transition to personalized medicine, where treatments are tailored to an individual's genetic makeup and specific disease characteristics. Nanoparticles can carry gene therapies or RNA-based therapies to correct genetic mutations or modulate gene expression, offering hope for previously untreatable genetic diseases. (Sate Rezin, B. I. 2024).

Until recently, there was no clear understanding of how nanotechnology could offer the right prospects for developing sustainability for industrial production. Most nanotech devices, as well as applied nanomaterials, are manufactured with production concepts that are far from sustainable, including the use of non-renewable resources and the distribution of toxic by-products and waste.

Conclusıon

Nanotechnology is poised to have a significant impact, particularly in the fields of regenerative medicine, tissue engineering, and electronics. However, challenges such as overcoming the toxicity of nanomaterials in the human body, creating efficient nanocatalysts, and developing chip fabrication for room-temperature quantum computing remain areas for future research.

As nanotechnology advances, the need for robust regulations and ethical guidelines also increases. Ensuring the safety of nanomaterials, their responsible use, and their potential environmental impacts are important issues. Researchers and policymakers are working together to create frameworks that balance innovation with safety.

In conclusion, current trends in nanotechnology research promise a remarkable future with groundbreaking innovations. From healthcare to electronics, from sustainability to quantum computing, the nanoscale continues to open up new possibilities. However, with great power comes great responsibility, and it is crucial to pay attention to safety and ethics as we move further into the nanoworld. The potential of nanotechnology is vast, and today's discoveries pave the way for a technologically advanced and sustainable tomorrow.

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PSYCHOLOGICAL SCIENCES

SYSTEM OF PSYCHOLOGICAL EDUCATIONAL WORK WITH SCHOOLCHILDREN FROM INCOMPLETE FAMILIES

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Abstract
The object of the activity of every social educator and worker is the child's personality. The child opens his eyes to the world in the family, from the first day he assimilates the norms of coexistence, takes from his family the good and the bad, in general, everything that is characteristic of that family, when he grows up, he repeats in his own family what he saw in the parental family, grows up, becomes socialized. In the family, the child's relationship with the surrounding world is regulated. He gains experience in spirituality, cultural norms of behavior. The family is the core, the foundation of society. In the life of every person, his family plays a special role. The issue of the family is such a big issue that it has been the object of research of various researchers for many years. When we look at the scientific and pedagogical literature, we can find different opinions on this issue. S. Guliyev notes that the state of the state depends on the state of the family. In the family, there is definitely a moral connection between parents and children. At the same time, there are connections between each family that forms the core of the state and various other families.

Keywords: family, connections, opinions, various researchers

The morality of each family, the morality of the state, the social status of each family is an indicator of the social status of the state, and the economic status of each family is an indicator of the economic status of the state. In addition to fulfilling social duties, the family cultivates a personality corresponding to its cultural, moral and social level. Socialization in the family depends on the composition of the family. Today, it can be said that there are no longer large families, such as those in previous times, that is, families with grandparents, aunts, uncles, etc. The formation of personality within the family changes depending on the relationship between family members.

In family relationships, family members usually have different expectations from each other. Thus, a woman wants to see her husband as a sincere, respectful, caring, courageous, intelligent person. Men, in turn, want to see their spouses as sincere, kind, caring, gentle, beautiful. Of course, the parties always bring these expectations to each other's attention before getting married. However, sometimes after getting married, some dissatisfaction arises. In this case, the man, the woman, or both parties may be dissatisfied. The reason for this may be that the parties encounter a completely different family model from the family model they have built in their minds. When this happens, divorce occurs.

There are various types of families. One of them is incomplete families.

An incomplete family is a single-parent family, the number of which has been increasing in recent years. In these families, the parent is usually the mother, and rarely the father. American researchers have found that in 2.8% of families, the father raises the child alone. Such families arise as a result of divorce, the death of one of the parents, or when a child is born out of wedlock. If the spouses do not live together, but in separate places, this is also considered an incomplete family. Such families need state care [5, P.114].

An unsuccessful family is essentially a sociological and socio-psychological phenomenon, its characteristics are mainly studied within the framework of these sciences. An unsuccessful family has many socio-psychological problems. An incomplete family is a purely demographic phenomenon. Each of the above-mentioned incomplete families has its own characteristics. However, what they have in common is that in each case the child grows up with only one parent.

In incomplete families resulting from death, each of the family members is deeply shaken to the same extent. Children from such families differ from children from other incomplete families in that they already know that they will never be able to see and communicate with the parent they have lost. This creates a feeling of lack in them. And the child lives with that feeling of lack throughout his life. This feeling always has its psychological impact on that person. Such people are always distinguished from their peers by their sensitivity.

Divorce and its consequences. Divorce, which is a global demographic process, is one of the greatest scourges of the 21st century. This process is characteristic of all developed countries. Since the 80s of the last century, this issue has become a problem that worries the world. Since then, various methods have been used to find a solution to such a big problem as divorce. Despite all the measures taken, the number of divorces continues to increase day by day. It should also be noted that the number and reasons for divorce are not the same in every country and city.

“A comparative analysis of demographic literature shows that divorce mainly occurs during the adolescence of children. Adolescence is one of the most complex periods in the formation of a student's personality. The formation of feelings and inclinations for adulthood is the main feature of that period. The formation of self-awareness and moral awareness in this age of

friendship and love attracts attention as a major event in the development of a student's personality" [5, p.255]

According to J. Kelly and J. Wallerstein, the bitter consequences of divorce have a completely negative impact on the personality of the child being formed, his spiritual and cultural world, his communication with friends, relatives, people, and his relationship with his mother and father. It causes the formation of negative qualities such as distrust, fear, and insecurity in children. For this reason, the consequences of the divorce process that occurs during a child's adolescence are more severe. In such cases, sharp differences between children's behavior at school and at home are evident. Not only do children's academic performance deteriorate, but their relationships and communication with people around them also deteriorate.

The period before divorce is also a very difficult period for a child. This period is characterized by psychologically and pedagogically difficult and complicated situations for both parents and children. Factors such as arguments, disagreements, quarrels, inappropriate behavior, insults, psychological trauma, violence, etc. between father and mother naturally have a huge impact on the child's psychology.

In families resulting from divorce, the conflict between mother and father almost never ends. Children often stay with their mother. In this case, mothers usually n create obstacles for their children to meet their fathers. The mother may have some reason for this. However, this can have certain negative effects on the child's growth, development and psychology. The inability to communicate normally with one of the parents, to use their help, to gain their sympathy and approval affects the child's psyche. The situation becomes even more complicated when the parents begin to make the child feel the hostile attitude between them. That is, the mother criticizes her ex-spouse in front of the child, accuses the child of being against him or, conversely, attributes all this to the father. At this time, the child is left between his two parents and is shaken.

Another feature of an incomplete family is the restructuring of external social relations. A single mother loses a number of acquaintances, because they were from her husband's side. At the same time, lack of time also makes it necessary to reduce external relations. This naturally worsens the child's social relations. This restriction in external relations is accompanied by difficulties in the emotional state of the mother in an incomplete family. Unstable work mood, increased irritability due to the spread of negative emotions due to excessive working hours - all this makes up the psychological microclimate of a single-parent family. Similar experiences, of course, also arise in a single-parent family. However, firstly, single-parent families are less common, and secondly, such families are often supported more intensively with the help of grandparents.

SOCIAL SCIENCIES

JEL: M12, O33, M15

PEDAGOGICAL FUNCTIONS OF AI-BASED SYSTEMS IN PROFESSIONAL ADAPTATION: A COMPARATIVE CONTENT ANALYSIS

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Abstract

The increasing integration of artificial intelligence (AI)–based systems into professional environments has intensified the need for systematic pedagogical analysis of their functions in workplace learning and professional adaptation. Existing research often conceptualizes AI in education at an abstract level or evaluates its impact through human-centered studies, while the pedagogical functions embedded within AI systems themselves remain insufficiently examined in a systematic empirical manner. This article addresses this gap by treating AI-based systems as empirical pedagogical artifacts and examining their functional properties through comparative content analysis.

The empirical basis of the study consists of a comparative analysis of five explicitly defined AI-based systems: ChatGPT, Gemini, Grok, Microsoft Copilot, and AI modules embedded in corporate Learning Management Systems (LMS). The study employs comparative content analysis and functional–pedagogical analysis, without involving human participants, surveys, or experimental interventions. A pedagogical function matrix was developed to analyze diagnostic support, feedback and formative assessment, support for reflection, individualization of learning and adaptation trajectories, pedagogical guidance and scaffolding, as well as pedagogical limitations and risks.

The results reveal significant variation in how pedagogical functions are operationalized across AI systems. General-purpose generative AI systems demonstrate strong dialogic feedback and reflective support but lack persistent individualization mechanisms, while corporate LMS AI modules provide structured diagnostics and adaptation pathways with limited dialogic interaction. Microsoft Copilot exhibits embedded pedagogical functions within work processes, whereas Grok shows minimal pedagogical structuring across most functions. The findings underscore that AI-based systems are pedagogically heterogeneous and cannot be treated as functionally equivalent in professional adaptation contexts. The study contributes a replicable methodological framework for empirical analysis of AI systems as pedagogical agents and informs future research on AI-supported workplace learning.

Index Terms

Artificial intelligence, workplace learning, professional adaptation, employee onboarding, comparative content analysis, generative AI, learning management systems, digital pedagogy, human–AI interaction, professional development

1 Introduction

The rapid diffusion of artificial intelligence (AI)–based systems into professional environments has intensified scholarly interest in their pedagogical roles within workplace learning and professional adaptation. While existing research has extensively discussed AI as a transformative force in education and training, much of this literature remains conceptual, speculative, or focused on human-centered evaluations such as learner perceptions, performance outcomes, or experimental interventions. Earlier work on AI in education has also emphasized the transformative potential of intelligent systems for learning support and instructional interaction (Luckin et al., 2016). As a result, the pedagogical functions embedded directly within AI systems themselves – independent of human users – remain insufficiently examined in a systematic and empirical manner.

This article addresses that gap by conceptualizing AI-based systems as empirical pedagogical objects. Specifically, it treats AI systems not as abstract technologies but as structured artifacts whose interfaces, response logics, feedback mechanisms, and instructional affordances can be subjected to systematic analysis. The study focuses on a comparative content analysis of five explicitly defined AI-based systems currently used or positioned for use in professional and workplace learning contexts: ChatGPT (OpenAI), Grok, Gemini, Microsoft Copilot, and AI modules embedded in corporate Learning Management Systems (LMS). Each of these systems represents a distinct design philosophy, governance model, and degree of integration into organizational learning infrastructures, making them suitable for comparative pedagogical analysis.

The central research premise is that AI systems operationalize pedagogical functions through their design and interaction logic, regardless of whether they are formally labeled as “educational technologies.” In line with approaches in educational technology re-

search and workplace learning studies, this article argues that analyzing the functional pedagogical properties of AI systems constitutes empirical research, insofar as it relies on observable, replicable, and systematically coded features of real digital artifacts. This position aligns with prior methodological work that recognizes documents, digital platforms, and algorithmic outputs as valid empirical material for content and functional analysis (Krippendorff, 2018). This position is also consistent with research traditions in workplace learning that treat digital systems and organizational artifacts as legitimate empirical objects of pedagogical analysis (Billett, 2011; Illeris, 2018).

The relevance of this inquiry is heightened by policy-level discussions on lifelong learning, reskilling, and workforce adaptation. International organizations such as UNESCO and the OECD emphasize the growing role of AI in shaping learning ecosystems and professional development, while simultaneously warning about risks related to transparency, pedagogical quality, and over-automation (OECD, 2021; OECD, 2023; UNESCO, 2023). However, these policy documents rarely differentiate between specific AI systems or examine how concrete pedagogical functions are implemented – or omitted – within them.

Accordingly, the aim of this article is not to evaluate the effectiveness of AI systems on real learners, nor to make claims about learning outcomes. Instead, the study pursues a narrower but methodologically rigorous objective: to identify, compare, and critically assess the pedagogical functions embedded in selected AI-based systems that are increasingly involved in professional adaptation processes. To achieve this, the article employs a pedagogical function matrix encompassing diagnostic support, feedback and formative assessment, support for reflection, individualization of learning and adaptation trajectories, pedagogical guidance and scaffolding, as well as limitations and pedagogical risks. By adopting a comparative content-analytic approach, this study contributes to the international discourse on AI in professional development in three ways. First, it advances a methodological framework for treating AI systems as empirical pedagogical artifacts. Second, it provides a structured comparison of widely used and emerging AI systems without collapsing them into a homogeneous category of "AI." Third, it offers a function-oriented perspective that can inform future research, design decisions, and regulatory discussions concerning AI-supported professional adaptation.

2 Methodology

2.1 Selection of AI-Based Systems

The selection of AI-based systems for this study was guided by the principle of pedagogical relevance within professional adaptation contexts and by the requirement of analytical comparability. The empirical base includes five systems: ChatGPT, Grok, Gemini, Microsoft Copilot, and AI modules embedded in corporate Learning Management Systems (LMS). These systems were not selected as representatives of "AI in general," but as concrete, widely deployed digital artifacts with distinct design logics and documented use in professional or workplace-related settings.

ChatGPT, developed by OpenAI, was selected due to its broad adoption across professional domains, including onboarding, informal learning, knowledge work, and self-directed upskilling. Its conversational architecture and general-purpose design allow for the observation of multiple pedagogical functions – such as feedback generation, reflection support, and scaffolding – without being formally embedded in an institutional learning environment.

Microsoft Copilot, developed by Microsoft, was included as an example of an AI system explicitly integrated into productivity and workplace ecosystems (e.g., Microsoft 365). Copilot represents a distinct category of AI-based support, where learning and adaptation functions are embedded implicitly within work processes rather than delivered as standalone educational interactions. This makes Copilot particularly relevant for analyzing pedagogical functions that operate "in the flow of work."

Gemini, developed by Google, was selected as a multimodal, large-scale generative AI system positioned for both general knowledge work and professional problem-solving. Its inclusion enables comparison between different design philosophies of general-purpose AI systems, particularly regarding reasoning transparency, guidance strategies, and interaction structure.

Grok, developed by xAI, was included as a contrasting case due to its emphasis on real-time information access, exploratory interaction, and minimal pedagogical framing. This system allows for the identification of pedagogical functions that emerge incidentally rather than being explicitly designed for learning or adaptation.

Finally, AI modules embedded in corporate LMS were included as a distinct category rather than as a single proprietary product. Examples include AI-driven recommendation engines, adaptive learning paths, and skill-gap analytics commonly implemented in enterprise platforms such as SAP SuccessFactors, Cornerstone, or Workday Learning. This category encompasses AI-driven functionalities commonly found in enterprise learning platforms (e.g., recommendation engines, skill-gap analytics, adaptive learning paths). The decision to treat corporate LMS AI as a category rather than a named product reflects their shared pedagogical intent and structural similarity, as documented in organizational learning literature and vendor-independent analyses (OECD, 2021). These systems are explicitly designed for professional development and adaptation, making them a critical comparative reference point. Together, these systems satisfy four selection criteria: (1) relevance to professional adaptation, (2) availability for systematic observation, (3) functional diversity, and (4) comparability at the level of pedagogical functions rather than technical architecture.

2.2 Construction of the Pedagogical Function Matrix

The analytical framework of the study is a pedagogical function matrix, developed to enable systematic comparison across heterogeneous AI systems. The matrix was constructed through a deductive–theoretical process grounded in established research on workplace learning, adult education, and formative assessment.

Table 1

Coding Scheme for Pedagogical Functions Used in the Comparative Content Analysis

Pedagogical function	Coding indicators (inclusion criteria)	Exclusion criteria
Diagnostic support	System infers user needs, gaps, or task deficiencies based on input	Pure information retrieval without inference
Feedback and formative assessment	Corrective, explanatory, or developmental responses guiding improvement	Neutral summaries or restatements
Support for reflection	Prompts encouraging self-analysis, reasoning, or evaluation	Procedural instructions without reflection
Individualisation	Adaptation across interactions or user profiles	One-time prompt customization
Pedagogical guidance and scaffolding	Progressive support enabling task or competence development	Single-step answers without progression
Pedagogical risks	Design-related constraints affecting learning processes	Technical errors unrelated to pedagogy

Note. Coding categories were applied uniformly across all analyzed systems to ensure functional comparability.

Six core pedagogical functions were defined:

1. Diagnostic support – the system's capacity to identify user needs, knowledge gaps, or task-related deficiencies based on input.
2. Feedback and formative assessment – the provision of evaluative, corrective, or developmental responses that inform subsequent action.
3. Support for reflection – prompts or structures that encourage users to analyze their own understanding, decisions, or performance.
4. Individualisation of learning or adaptation trajectories – the system's ability to adjust responses, recommendations, or pathways based on user-specific inputs.
5. Pedagogical guidance and scaffolding – structured support that helps users progress from current to more advanced levels of competence.
6. Limitations and pedagogical risks – constraints, omissions, or risks inherent in the system's design (e.g., lack of transparency, over-reliance on automation).

These functions were operationalized as analytical codes. Each code was defined with inclusion and exclusion criteria to ensure consistency. For example, adaptive response variation based solely on prompt phrasing was coded differently from systematic personalization mechanisms embedded in LMS AI.

The matrix does not assume that all systems should perform all functions equally. Instead, it serves as a neutral analytical tool for identifying presence, absence, strength, or weakness of each pedagogical function within each system.

2.3 Comparative Content Analysis Procedure

The empirical analysis employed comparative content analysis combined with functional-pedagogical analysis. This analytical strategy is consistent with established qualitative approaches to systematic coding and interpretation of textual material (Braun & Clarke, 2006; Krippendorff, 2018). The unit of analysis was not the AI system as a whole, but its observable interactional outputs and functional affordances as documented through systematic interaction scenarios and feature examination.

For each AI system, a standardized set of professional adaptation-oriented tasks was used (e.g., onboarding-related problem-solving, skill development inquiries, task clarification). System outputs were documented and coded according to the pedagogical function matrix. In the case of corporate LMS AI, publicly available documentation and demonstrative system behaviors described in peer-reviewed and policy literature were analyzed as empirical material.

Comparability was ensured by:

– applying the same functional codes across all systems;

– analyzing systems at the level of pedagogical function rather than technical implementation;

– excluding claims about learner outcomes or user experience.

Replicability is supported by the explicit definition of systems, functions, and coding rules. Another researcher, using the same interaction prompts and coding scheme, would be able to reproduce the analytical logic and arrive at comparable categorizations, even if specific outputs vary due to system updates.

Crucially, this approach treats AI systems as stable empirical artifacts for the purposes of functional analysis. While their outputs may evolve, their pedagogical roles at a given point in time remain observable and analyzable, thereby fulfilling the criteria of empirical research within qualitative and content-analytic traditions (Krippendorff, 2018).

In this sense, AI system outputs and documented functional affordances are treated as empirical textual material, comparable to policy documents, curricula, or digital learning environments traditionally analyzed in pedagogical content analysis.

Table 2

Pedagogical Function Matrix for AI-Based Systems in Professional Adaptation

Pedagogical function	ChatGPT	Gemini	Grok	Microsoft Copilot	Corporate LMS AI modules
Diagnostic support	Moderate (implicit, prompt-driven inference)	Moderate (implicit, context-based inference)	Weak (limited inference)	Context-bound (task-level diagnostics)	Strong (explicit, profile- and competency-based)
Feedback and formative assessment	Strong (dialogic, explanatory feedback)	Strong (analytical, explanatory feedback)	Weak (reactive, non-developmental)	Moderate (procedural feedback embedded in tasks)	Moderate (structured, rubric- or metric-based)
Support for reflection	Strong (frequent reflective prompting)	Moderate (conditional reflective support)	Weak (minimal reflective framing)	Weak (reflection not explicitly supported)	Weak (optional, non-dialogic reflection)
Individualisation of learning or adaptation trajectories	Situational (interaction-dependent)	Situational (interaction-dependent)	Minimal (prompt-level variation only)	Task-based (contextual adaptation)	Strong (systematic, profile-driven pathways)
Pedagogical guidance and scaffolding	Emergent (stepwise explanations on demand)	Partial (analytical scaffolding)	Minimal (exploratory responses)	Procedural (workflow-oriented guidance)	Structured (predefined learning sequences)
Pedagogical limitations and risks	Over-scaffolding; cognitive offloading	Over-reliance on AI explanations	Under-structuring; lack of guidance	Invisible learning processes	Pedagogical rigidity; limited dialogicity

Note. The table reflects a comparative content analysis of observable system functions. Ratings indicate relative presence or absence of pedagogical functions and do not imply effectiveness for learners.

3 Empirical Analysis and Results

This section presents the results of the comparative content analysis based on the pedagogical function matrix. The analysis focuses on observable pedagogical functions embedded in AI system behavior and design, not on learning outcomes or user effectiveness. Table 2 provides a structured overview of the comparative results and serves as a reference framework for the following subsections. Each system – ChatGPT, Grok, Gemini, Microsoft Copilot, and corporate LMS AI modules – was analyzed against the same set of pedagogical functions to ensure comparability.

3.1 Diagnostic Support

Clear differences emerged in the degree and form of diagnostic support across systems.

Corporate LMS AI modules demonstrate the most explicit diagnostic functionality. These systems typically rely on structured user data (e.g., role profiles, competency frameworks, prior training records) to identify skill gaps and adaptation needs. Diagnostic support is formalized through dashboards, readiness indicators, or automated skill-gap analyses.

ChatGPT and Gemini exhibit implicit diagnostic support. They infer user needs dynamically from prompts, prior conversational context, and task framing. While neither system performs formal assessment, both are capable of diagnosing misunderstandings or incomplete knowledge when users articulate problems explicitly.

Microsoft Copilot provides context-bound diagnostic support. Its diagnostic capacity is limited to the immediate work environment (documents, emails, code, or spreadsheets). It identifies issues related to task execution rather than broader professional adaptation needs.

Grok shows the weakest diagnostic function. Its interaction style prioritizes information retrieval and exploratory dialogue, offering minimal inference about user competence or adaptation state.

3.2 Feedback and Formative Assessment

Feedback mechanisms vary substantially in pedagogical depth.

ChatGPT and Gemini provide rich, language-based formative feedback, including explanations, alternative solutions, and corrective suggestions. Feedback is dialogic and iterative, allowing users to refine

understanding over multiple turns. Corporate LMS AI modules offer structured but narrower feedback. Feedback is often rubric-based or competency-aligned, focusing on completion status, correctness, or progression metrics rather than conceptual understanding. Microsoft Copilot delivers feedback embedded in task execution, such as suggested revisions or efficiency improvements. While actionable, this feedback is not explicitly framed as formative assessment. Grok provides reactive feedback with limited pedagogical framing. Responses tend to prioritize immediacy and novelty over developmental guidance.

3.3 Support for Reflection

Support for reflective processes is unevenly distributed.

ChatGPT demonstrates the strongest capacity for reflection support. It frequently prompts users to reconsider assumptions, evaluate alternatives, or articulate reasoning. Reflection emerges as a by-product of conversational depth rather than as a predefined instructional strategy.

Gemini offers moderate reflection support, particularly in analytical or problem-solving contexts, though reflection prompts are less consistent.

Corporate LMS AI modules provide minimal reflection support. Reflection, when present, is often optional and structured (e.g., post-module self-assessments) rather than dialogic.

Microsoft Copilot and Grok show limited reflective functionality. Their designs prioritize task completion and information access, leaving reflection largely to the user.

3.4 Individualisation of Learning and Adaptation Trajectories

Individualisation constitutes a major differentiating factor.

Corporate LMS AI modules demonstrate the most systematic individualisation. Learning paths, content recommendations, and pacing are adjusted based on user profiles and performance indicators.

ChatGPT and Gemini enable interaction-driven individualisation. Responses adapt dynamically to user input, but this individualisation is ephemeral and not anchored in long-term learner models.

Microsoft Copilot individualises support at the level of task context, not learner development. Adaptation is situational rather than developmental.

Grok shows minimal individualisation beyond prompt-level customization.

3.5 Pedagogical Guidance and Scaffolding

Pedagogical scaffolding is strongest where instructional intent is explicit.

Corporate LMS AI modules employ predefined scaffolding structures aligned with organizational competency frameworks. Guidance is linear and goal-oriented but often inflexible.

ChatGPT provides emergent scaffolding through step-by-step explanations, examples, and adaptive questioning. However, scaffolding depends heavily on user prompting and lacks formal progression control.

Gemini offers partial scaffolding, particularly in analytical domains, but with less conversational persistence.

Microsoft Copilot provides procedural guidance embedded in workflows rather than conceptual scaffolding.

Grok shows limited scaffolding, emphasizing exploration over structured progression.

3.6 Limitations and Pedagogical Risks

Across systems, several pedagogical risks were identified.

ChatGPT and Gemini risk over-scaffolding and cognitive offloading, potentially reducing learner agency if used uncritically. Their lack of explicit boundary-setting between assistance and instruction is a notable limitation.

Corporate LMS AI modules risk pedagogical rigidity. Their reliance on predefined competency models may constrain adaptive learning and overlook informal or emergent skills.

Microsoft Copilot risks obscuring learning processes by embedding guidance invisibly within productivity tasks, potentially limiting metacognitive awareness.

Grok presents risks related to insufficient pedagogical framing, which may hinder structured professional adaptation.

3.7 Comparative Summary

Overall, the analysis reveals a functional trade-off between flexibility and structure. General-purpose AI systems (ChatGPT, Gemini) excel in dialogic feedback and reflection but lack durable individualisation mechanisms. Corporate LMS AI modules offer structured diagnostics and adaptation pathways but weaker reflective and dialogic functions. Microsoft Copilot occupies an intermediate position, embedding limited pedagogical functions within work processes. Grok consistently exhibits the weakest pedagogical profile across most functions.

These findings underscore that AI-based systems differ not only in technical architecture but in the pedagogical roles they implicitly or explicitly perform during professional adaptation.

4 Discussion

The empirical analysis demonstrates that AI-based systems operationalize pedagogical functions in markedly different ways, even when they are positioned within similar professional or workplace contexts. Treating these systems as empirical pedagogical artifacts makes it possible to move beyond abstract claims about “AI in education” and to identify concrete functional configurations that shape professional adaptation processes.

A first key finding concerns the structural divide between dialogic and system-driven pedagogy. General-purpose generative systems such as ChatGPT and

Gemini exhibit strong dialogic capacities: they support reflection, provide elaborated formative feedback, and enable situational scaffolding through language-based interaction. These functions align with constructivist and reflective approaches to adult learning, particularly in informal or self-directed professional adaptation. However, these systems lack persistent learner models and formalized progression logic, which limits their capacity to support long-term adaptation trajectories in organizational contexts.

In contrast, corporate LMS AI modules embody an institutionalized pedagogical logic. Their strengths lie in diagnostic support, standardized individualization, and alignment with predefined competency frameworks. From the perspective of organizational training research, such functions are especially relevant for structured workplace development and competence formation (Salas et al., 2012). From a pedagogical perspective, this reflects a performance-oriented model of professional adaptation, consistent with human capital and skills-management approaches described in OECD workplace learning frameworks (OECD, 2021; OECD, 2023). Yet, the analysis shows that this strength comes at the cost of reduced dialogicity and weak support for reflection, which are critical for deeper professional learning and identity formation.

Microsoft Copilot occupies a hybrid position that is pedagogically significant. Its integration into everyday work processes exemplifies what can be described as embedded pedagogy: learning support is delivered implicitly through task execution rather than explicit instructional interaction. While this aligns with theories of learning "in the flow of work," the analysis suggests a pedagogical risk: the invisibility of learning processes may undermine metacognitive awareness and reflective adaptation. In this sense, Copilot supports efficiency-oriented adaptation more than developmental learning.

Grok represents a contrasting case where pedagogical functions are largely incidental rather than designed. Its emphasis on immediacy, exploration, and real-time information access results in weak diagnostic, scaffolding, and individualization functions. From a pedagogical standpoint, Grok illustrates the lower boundary of pedagogical integration in AI systems: learning-relevant functions may emerge, but they are neither systematic nor reliable for professional adaptation purposes.

To synthesize the comparative findings, Figure 1 presents a conceptual positioning of the analyzed AI-based systems along two analytical dimensions: degree of pedagogical structure and degree of dialogic–reflective support. The figure highlights systematic trade-offs identified in the empirical analysis, illustrating how different design logics privilege either structured adaptation pathways or dialogic and reflective pedagogical functions. This synthesis supports the interpretation of AI systems as pedagogically heterogeneous artifacts rather than functionally equivalent tools for professional adaptation.

Taken together, these findings suggest that pedagogical functionality in AI systems is not a function of technical sophistication alone, but of design intent, governance context, and assumptions about learning. Systems developed primarily for productivity or information access tend to underperform in reflective and developmental functions, whereas systems designed for learning management often sacrifice flexibility and dialogic depth. This supports UNESCO's position that pedagogical considerations must be embedded explicitly in AI system design, rather than treated as secondary outcomes (UNESCO, 2023). A similar emphasis on ethical and pedagogically informed use of AI in learning environments is reflected in European policy guidelines (European Commission, 2022). This observation resonates with instructional design research emphasizing that pedagogical quality emerges from design logic rather than technological complexity alone (van Merriënboer & Kirschner, 2018).

Importantly, the comparative analysis also reveals missing pedagogical functions across all systems. None of the analyzed AI-based systems demonstrate robust mechanisms for ethical guidance, boundary-setting of learner autonomy, or explicit support for the gradual withdrawal of scaffolding – functions traditionally associated with mature pedagogical models. This absence highlights a structural gap between AI-enabled support and established theories of adult and workplace learning.

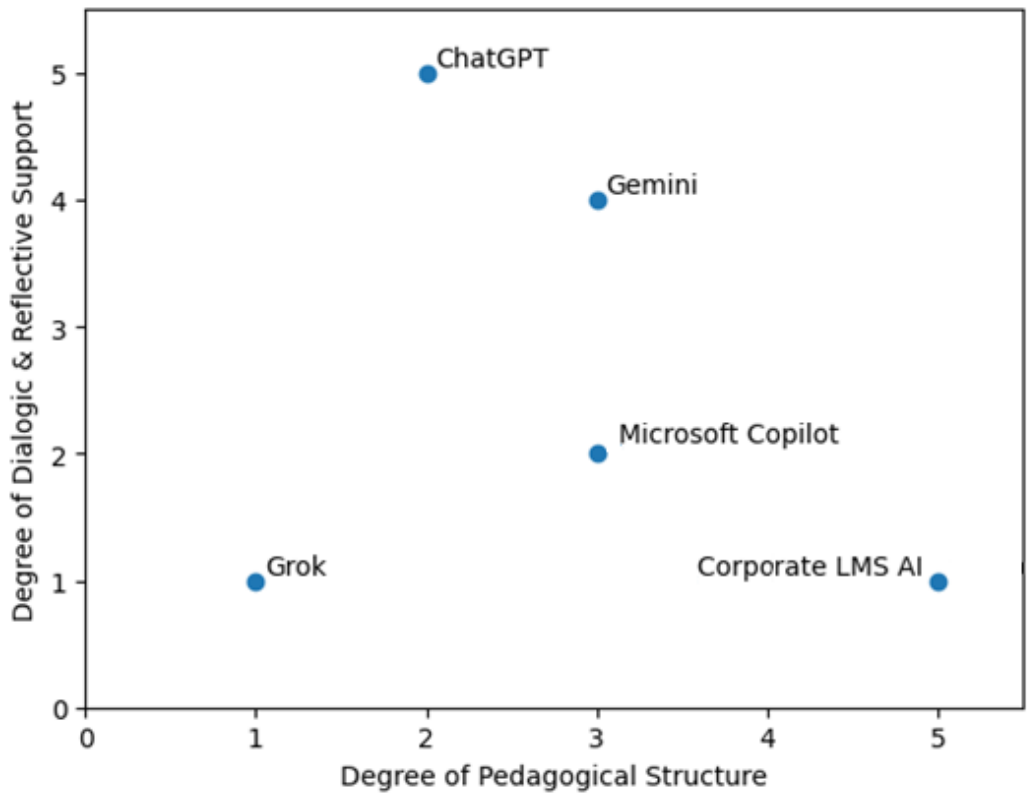

Figure 1. *Conceptual synthesis of pedagogical structure and dialogic–reflective support across AI-based systems. Note: the figure represents an analytical positioning derived from comparative content analysis. Axes indicate relative emphasis on pedagogical structure and dialogic–reflective support and do not represent quantitative measurement or learner outcomes.*

5 Limitations

This study has several limitations that should be acknowledged.

First, the analysis is limited to a content-analytic and functional perspective. It does not examine how real learners or employees interact with these systems, nor does it assess learning outcomes, behavioral change, or organizational impact. Consequently, no claims are made about effectiveness, efficiency, or learner experience.

Second, AI systems are evolving artifacts. The analysis captures pedagogical functions as observable at a specific point in time. Subsequent updates to system architecture, policies, or interfaces may alter functional characteristics, although the analytical framework itself remains applicable.

Third, the category of corporate LMS AI modules is treated as a functional class rather than as individual branded systems. While this approach enhances generalizability at the pedagogical level, it reduces granularity with respect to specific vendor implementations.

Finally, the study focuses exclusively on AI systems as pedagogical agents, excluding the broader sociotechnical context in which they are embedded. Organizational culture, human trainers, and regulatory frameworks are not analyzed, even though they significantly shape professional adaptation in practice.

Additionally, the analysis does not account for organizational mediation effects, where human trainers or institutional policies may amplify or constrain the pedagogical functions of AI systems in practice.

Despite these limitations, the study provides a replicable methodological model for analyzing AI-based systems as empirical pedagogical objects and offers a structured basis for further comparative and design-oriented research.

6 Conclusion

This article set out to examine AI-based systems as empirical pedagogical artifacts within the context of professional adaptation, rather than as abstract or purely technological phenomena. By applying a comparative content analysis and a functional-pedagogical framework to ChatGPT, Grok, Gemini, Microsoft Copilot, and AI modules embedded in corporate LMS, the study demonstrates that AI systems embody distinct pedagogical logics that shape how professional adaptation is supported, constrained, or redirected.

The findings show that pedagogical functionality is unevenly distributed across systems. General-purpose generative AI systems (ChatGPT and Gemini) provide strong dialogic feedback, reflection support, and situational scaffolding, but lack persistent individualisation and formal diagnostic structures. Corporate LMS AI modules, by contrast, excel in structured diagnostics and individualized adaptation trajectories aligned with organizational competency models, while offering limited support for reflection and dialogic learning. Microsoft Copilot illustrates an emergent model of embedded pedagogy, where learning support is integrated into work processes but remains largely

implicit. Grok, finally, demonstrates that without explicit pedagogical intent, learning-relevant functions remain weak and inconsistent.

From a methodological perspective, the study confirms that the systematic analysis of AI systems themselves constitutes empirical research, provided that the objects of analysis, coding procedures, and comparison criteria are explicitly defined and replicable. This approach responds to calls from international organizations and the research community to move beyond speculative narratives about AI in education toward evidence-based, function-oriented analysis.

Theoretically, the results suggest that current AI-based systems only partially operationalize established pedagogical principles of adult and workplace learning. Across all systems, critical functions such as sustained learner modeling, ethical scaffolding, and the gradual withdrawal of support remain underdeveloped. Practically, the findings caution against treating AI systems as pedagogically neutral tools: their design choices actively shape forms of professional adaptation, autonomy, and dependence.

Future research may extend this framework to longitudinal system comparisons, regulatory analyses, or hybrid human–AI pedagogical models. However, such work should continue to distinguish clearly between what AI systems are pedagogically capable of and what learners or organizations actually achieve with them. Maintaining this distinction is essential for the theoretical maturity and empirical rigor of research on AI in professional development.

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TECHNICAL SCIENCES

CYBER-RESILIENT HOSPITAL OPERATIONS AFTER THIRD-PARTY CLAIMS FAILURE: A RISK-WORKFLOW FRAMEWORK

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Abstract

Third-party claims failure reveals a hospital vulnerability that conventional cyber-defense models explain only partially. Operational continuity may deteriorate even when local clinical systems remain available because hospital workflows depend on external eligibility, authorization, pharmacy, remittance, and claims intermediaries. Recent healthcare cyber-resilience research has broadened, yet process-level modeling of vendor-to-hospital dependency cascades remains underdeveloped. This article addresses that gap through a conceptual-comparative framework positioned in the discipline of Modeling and Analysis of Information Systems. The study combines graph-based dependency modeling with a resilience-oriented risk-workflow framework and applies it to three disruption configurations: internal hospital core-system failure, single-vendor claims failure, and tightly coupled multi-node dependency disruption. The analytical unit is the hospital service workflow rather than the isolated technical asset. The framework formalizes external dependency nodes, propagation paths, continuity exposure, containment options, and recovery bottlenecks. It also proposes a compact metric system centered on critical node centrality, cascade depth, service-continuity exposure, dependency concentration, and recovery complexity. The main conclusion is that third-party claims failure produces a distinct resilience profile characterized by distributed care-adjacent disruption, delayed degradation, strong concentration effects, and externally constrained recovery, which justifies workflow-centered analysis in Information Systems research.

Keywords: hospital information systems, cyber resilience, third-party dependency, workflow modeling, service continuity, inter-organizational systems, graph-based risk analysis.

Hospitals may lose operational continuity even when local clinical platforms remain technically available if a transactionally central external claims intermediary fails. The 2024 Change Healthcare incident demonstrated this condition at system scale: a survey of nearly one thousand hospitals found that 74% reported direct patient-care disruption and 94% reported financial harm after the event [1].

The incident also exposed the concentration of digital transaction infrastructure. Federal emergency payment measures and subsequent regulatory commentary showed that interrupted claims flows created a continuity shock for providers rather than a routine administrative delay, which means the event must be treated as an operational dependency problem rather than as a narrow billing outage.

A study of the CrowdStrike outage found patient-care technology disruptions in 759 of 2232 hospitals and showed that many affected services were not directly patient-facing, which underlines the analytical importance of care-adjacent workflows for hospital operations [2].

Healthcare cyber-resilience research remains methodologically uneven. A systematic review by Pavão et al. concluded that cyber-resilience solutions in healthcare information systems are still immature and often weakly evaluated in operational terms, which makes workflow-level formalization especially necessary [3].

More recent work has widened the field but still does not model claims-path dependencies with sufficient precision. Ewoh et al. proposed a sociotechnical cybersecurity framework for healthcare, yet their constructs remain broad and institution-centered rather than explicitly graphing vendor-to-hospital process dependencies [4].

Interdependence modeling research further supports the need for a cross-boundary analytical framework. Tong et al. showed that resilience in interdependent infrastructure networks depends on coupling density, substitution capacity, and cascade behavior, all of which are central for understanding how claims failure can propagate into hospital operations [5].

Problem Statement and Research Gap

The practical problem is the fragility of hospital operations when externally controlled claims-processing infrastructure becomes unavailable or degraded. The analytical problem is that this fragility is commonly described either as a generic cyber incident or as a narrow financial-administrative disruption. Neither description captures the actual object of analysis, which is the inter-organizational workflow linking vendor nodes to hospital service production.

The primary research question is as follows: how can third-party claims failure be modeled as an inter-

organizational hospital Information Systems dependency problem that explains cascade paths, service-continuity exposure, containment logic, and recovery bottlenecks? Supporting questions concern the structural criticality of external nodes, the comparative continuity profiles of different disruption configurations, and the resilience mechanisms most likely to reduce blast radius when hospitals do not control upstream transaction nodes.

The gap addressed in this article is specific: current studies do not provide a workflow-centered, graph-based, and comparative model of vendor-side claims failure in hospital operations. That absence matters because concentrated third-party intermediaries can impair many hospitals without disabling their internal core systems.

Methodology

This study uses a conceptual-comparative and scenario-based analytical design grounded in verified incident statistics, scientific literature, and dependency scenarios derived from real hospital-vendor relationships. No proprietary hospital process logs are claimed. The method is appropriate because the contribution lies in formalizing the structure and behavior of dependency chains rather than estimating one hospital's empirical parameters from a private dataset.

The object of analysis is inter-organizational hospital operations under digital disruption. The subject of analysis is the topology that links upstream vendor nodes, hospital process nodes, service nodes, and resilience mechanisms through propagation, containment, and recovery logic. The unit of analysis is the hospital service workflow, defined as the minimum structured sequence of information and coordination dependencies required for a hospital service state to remain functionally available.

Analytically, the operating environment is represented as a directed dependency graph $G = (V, E)$, where V contains external dependency nodes, hospital process nodes, service nodes, and resilience nodes. A workflow remains operational only if at least one admissible path exists between the nodes required for completion. Failure propagates when a mandatory edge is disabled and no effective substitute path exists. The comparison is organized across three configurations: internal hospital core-system failure, single-vendor claims failure, and tightly coupled multi-node dependency disruption.

Framework for Modeling Third-Party Claims Failure in Hospital Operations

The proposed framework treats third-party claims failure as a service-dependency cascade rather than as a narrowly financial outage. External dependency nodes include claims clearinghouses, payer gateways, prior-authorization interfaces, pharmacy transaction exchanges, and remittance channels. Hospital process nodes include registration, scheduling, coding, billing, discharge coordination, and local work queues. Service nodes represent operational outputs such as medication dispensing, elective procedure progression, discharge completion, and claim-to-cash continuity.

The framework separates direct clinical exposure from care-adjacent operational exposure. Direct clinical exposure occurs when the failure reaches nodes required for immediate care execution. Care-adjacent exposure occurs when disruption primarily affects eligibility confirmation, authorization, pharmacy adjudication, claim submission, or reimbursement. This distinction is analytical rather than normative because care-adjacent disruption can still delay admissions, postpone procedures, constrain discharge, and weaken operational capacity.

Resilience is modeled through four phases: absorption, containment, adaptation, and recovery. Absorption covers temporary preservation through buffers and manual handling. Containment covers prioritization, segmentation, or alternate routing. Adaptation covers degraded reconfiguration, such as delayed submission or exception pathways. Recovery covers restoration, reconciliation, and backlog clearance.

Scenario-Based Comparative Analysis

In the internal hospital core-system failure scenario, the initiating disruption occurs inside the provider environment. Because the failed nodes are clinically proximal, direct clinical exposure tends to be high and degradation is often immediate; departmental mitigation studies confirm that continuity in this configuration depends heavily on local preparedness and fallback routines [6].

In the single-vendor claims failure scenario, the initiating disruption is upstream and externally controlled. Core hospital systems may remain locally available, yet transaction-dependent workflows become degraded because the hospital cannot validate eligibility, secure authorization, exchange pharmacy information normally, submit claims, or complete remittance-linked sequences. This configuration tends to produce lower initial direct clinical impairment than some internal outages, but broader care-adjacent exposure, stronger concentration effects, and externally constrained recovery.

In the tightly coupled multi-node dependency scenario, several logically distinct but operationally convergent external nodes are degraded at once. Large-scale interdependence modeling shows that tight coupling increases cascade depth and complicates recovery, which in hospital terms means weaker substitution capacity, deeper workflow fragility, and a higher probability that care-adjacent disruption will evolve into broader service degradation [7].

Metrics and Evaluation Logic

The framework requires metrics that correspond to workflow dependency rather than attack taxonomy alone. Critical node centrality measures how strongly a node conditions weighted service continuity. Cascade depth measures how far the initiating failure propagates across the graph. Service-continuity exposure identifies the weighted share of hospital service capacity impaired by a given failure. Dependency concentration captures the share of workflows reliant on the top one or top k external nodes. Recovery path complexity estimates the number of coordinated restoration and reconciliation steps needed to return a workflow to stability.

These metrics are intended as an analytical evaluation grammar rather than a fabricated dataset. Verified

incident evidence supports the existence of broad patient-care, financial, and concentration effects under third-party claims failure. What remains scenario-based in this paper is the exact numerical value of each metric for a specific hospital.

Discussion

The framework shifts cyber-resilience analysis away from isolated technical assets and toward service-producing information workflows that cross organizational boundaries. This move matters because hospitals may appear locally available while still suffering serious continuity loss through shared external intermediaries. It also clarifies why care-adjacent functions should not be treated as analytically secondary: they condition access, timing, discharge, reimbursement, and therefore service viability.

A second implication concerns governance. Inter-organizational systems and process-governance research imply that resilience depends not only on local downtime readiness but also on knowledge of external chokepoints, substitute paths, and coordination burdens. A hospital may have competent incident response and still remain fragile if its most central claims pathway has no tested substitute.

Conclusion

This article has argued that third-party claims failure should be modeled as an inter-organizational Information Systems dependency problem rather than as a narrow billing interruption or a generic cyber event. The literature is stronger on controls, preparedness, and generalized resilience than on formal workflow-centered analysis of vendor-dependent continuity. To address that gap, the article proposed a graph-based dependency model and a resilience-oriented risk-workflow framework that treat hospital service continuity as the product of layered inter-organizational pathways.

The comparative analysis showed that third-party claims failure has a distinct continuity profile: lower initial direct clinical impairment than some internal failures, broader care-adjacent exposure, stronger concentration effects, delayed degradation, and more difficult recovery. The framework contributes to Modeling and Analysis of Information Systems by relocating hospital cyber-resilience analysis from isolated assets to structured service dependency chains across organizational boundaries.

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PROPOSED NURSING SYSTEM AT UNIVERSITY OF STATE

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PROPUESTA SISTEMA DE ENFERMERÍA EN UNIVERSIDAD ESTATAL

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Abstract

A proposal for a prototype design of an information management system developed at a state university is presented. This system meets the current requirements for the study. The system provides solutions for control, management, and informed decision-making. Analyses were incorporated based on user experience and symptoms, yielding favorable results. Although the project focuses on design, it establishes a robust model for technological implementations in universities, achieving high levels of accuracy and efficiency at a low cost. Information is collected from the institutional information system, and based on this information, vital signs, user registration, and personal data are integrated with user consent.

Resumen

Se presenta una propuesta de un diseñó un prototipo de sistema de administración de información desarrollado en una Universidad Estatal la cual cumple las cláusulas reales para el estudio. El sistema permite dar soluciones de control, gestión y toma de decisiones informadas. Se incorporaron análisis de acuerdo a la experiencia y síntomas de los usuarios, alcanzando resultados favorables. El proyecto establece un modelo robusto para implementaciones tecnológicas en algunas de las Universidades, alcanzando niveles altos de precisión y eficiencia a bajo costo. Se recopila información del Sistema Institucional de Información, y en función de ello se integran los signos vitales, matrícula del usuario, datos personales bajo el consentimiento de los mismos.

Keywords: Evolutionary prototyping, Information management, Automated system, University nursing, Clinical digitization, Nursing system proposal at State University

Palabras Clave: Prototipado evolutivo, Gestión de información, Sistema automatizado, Enfermería universitaria, Digitalización clínica.

1.0 Introducción

Al realizar una exploración de la diversidad de los sistemas de atención médica alrededor del mundo, se identificaron desafíos que enfrentar y se han observado soluciones innovadoras que se están implementando para superar estos obstáculos [1].

En años recientes, la colaboración internacional ha sido un punto fundamental en el desarrollo teorías, prácticas, modelos educativos, experiencias de servicios, integración de sistemas de Inteligencia Artificial, administración de sistemas de salud, mejorar la calidad de servicio, desarrollar sistemas eficientes en atención de enfermería o médica. [2]. Una de las tendencias es desarrollar conocimientos, compartir experiencia y habilidades interpersonales en investigación, empleando habilidades integradas de comunicación, así las actividades relacionadas con la salud incluyen conferencias, redes y prácticas de salud tanto local como global, que brindan al personal y a los estudiantes oportunidades para incorporar acciones de mejora en el aprendizaje y sus habilidades para mejorar la salud a escala internacional, impactando con la interculturalidad a la que se tiene alcance hoy en día. Se han reportado beneficios como el desarrollo del liderazgo, la mejora en la comunicación intercultural y las competencias culturales, así como la exposición de diversos sistemas de salud [2,3]

En las últimas décadas, la salud global en mayor número de ocasiones se reconoce como relevante para los sistemas de salud, lo que ha impulsado el desarrollo de la educación y la capacitación en salud, predominantemente en países de mayores ingresos. Un caso específico es el del Reino Unido, en el que la inclusión de

planes de estudio voluntarios de salud global en cursos universitarios y programas de voluntariado individual ha existido durante muchas décadas. Durante la última década, la participación en salud global entre los profesionales y estudiantes de salud del Reino Unido ha crecido, y casi todas las escuelas de medicina ahora ofrecen módulos electivos de salud global y muchas organizaciones del Servicio Nacional de Salud (NHS) ahora apoyan la participación en actividades de salud global entre el personal [3].

En otro sentido en cuestión de inversión algunas naciones avanzadas como Estados Unidos de América, la atención médica está ampliamente influenciada por la inversión del sector privado, lo que genera un sistema donde el mercado de servicios médicos privados estableciéndose de manera predominante el acceso y la calidad de servicios de la atención. En contraste un modelo distinto también lo presenta el Reino Unido, en el que se maneja un sistema financiado con fondos públicos a través del Servicio Nacional de Salud (NHS), con el que lleva la atención médica como un derecho universal y gratuito en el punto de uso. Sin embargo, en Alemania se presenta un enfoque mixto, alcanzando un sistema integral de atención médica [1].

Visualizando en otro tipo de servicios, los servicios de enfermería en las instituciones también tienen retos y oportunidades, hoy se puede observar que la precisión y la eficiencia son esenciales, muchas universidades enfrentan desafíos significativos en la gestión de sus servicios de enfermería. La persistencia de procesos manuales para el registro y manejo de información ha derivado en errores frecuentes, duplicación de datos y pérdida de trazabilidad clínica, lo cual impacta negativamente en la calidad del servicio ofrecido. Está documentado que una identificación incorrecta de pacientes puede derivar en historiales médicos solapados o duplicados, generando riesgos para la seguridad del paciente y problemas legales para las instituciones [4].

La falta de control adecuado sobre las condiciones de salud de los pacientes puede tener consecuencias graves, como diagnósticos tardíos, seguimiento ineficiente de enfermedades crónicas y atención inadecuada en situaciones de emergencia. La Organización Mundial de la Salud destaca que eventos adversos prevenibles, como errores en la identificación de pacientes y fallos en la prescripción de medicamentos, son comunes y pueden tener efectos devastadores en la salud del paciente [5].

Para abordar estos desafíos, diversas instituciones han implementado soluciones tecnológicas digitales, como sistemas de registro electrónico de salud y aplicaciones móviles para el seguimiento de pacientes. Sin embargo, estas soluciones a menudo enfrentan limitaciones, incluyendo problemas de interoperabilidad, falta de capacitación del personal y resistencia al cambio, lo que puede limitar su efectividad [6-7].

En las investigaciones se ha documentado la importancia de relacionar los procesos y flujos de trabajo como el motor del sistema digital, la utilización de interfaces humano-dispositivo y el factor humano de manera definitiva, acompañados de una evaluación y monitoreo deriva en la mejora continua [7].

Aprovechando esos beneficios obtenidos y documentados, se desarrolló un proyecto que busca transformar la gestión de la información en el área de enfermería mediante la implementación de un sistema automatizado utilizando las tecnologías de información disponibles y alcance. Este sistema fue estructurado en varias etapas clave: desde una exhaustiva evaluación de las necesidades del usuario hasta el diseño y desarrollo de un prototipo funcional. Entre sus principales funcionalidades se incluyen el registro de pacientes, la generación de reportes, la gestión de usuarios y la recuperación de contraseñas en un servicio que originalmente se lleva de manera física.

Lo que distingue a este proyecto es su enfoque en la retroalimentación de los usuarios finales durante las pruebas de aceptación. Este proceso permitió realizar mejoras significativas que garantizaron una interfaz intuitiva y una experiencia de usuario óptima. Así mismo, esta estrategia se alinea con lo señalado por Benavente-Rubio, donde se destaca que el rol de enfermería en entornos digitales debe estar respaldado por sistemas centrados en el usuario y adaptables a su dinámica operativa, promoviendo una participación activa del personal en el diseño y validación de las herramientas tecnológicas (6).

La implementación de este sistema automatizado no solo reduce los errores y tiempos asociados a la gestión manual de datos, sino que también liberará recursos que podrán ser utilizados para mejorar otros aspectos del servicio. Además, contribuirá a una mejor administración de los recursos humanos y materiales en la atención institucional de la salud.

2.0 METODOLOGÍA

La metodología utilizada en este proyecto fue el prototipado evolutivo, un enfoque de desarrollo de software centrado en el usuario que permite la construcción progresiva del sistema mediante retroalimentación continua como lo presentó Pressman. Esta metodología es especialmente útil en entornos donde los requerimientos no están completamente definidos desde el inicio, como ocurre en áreas clínicas con necesidades cambiantes [8].

El proceso seguido se divide en cuatro fases principales, representadas en la Figura 1.

Figura 1. Bocetos de las interfaces principales.

2.1 Materiales y herramientas

Para la construcción y validación del sistema de gestión de información en el área de enfermería se emplearon recursos tanto de hardware como de software. La selección de estos materiales se realizó con base en criterios de disponibilidad institucional, compatibilidad tecnológica y facilidad de implementación (Tabla 1).

Tabla 1:

Recursos

Categoría	Recurso
Hardware	Laptop/PC (Intel i5, 8 GB RAM, Windows 11)
	Servidor local con Apache 2.4
	Red institucional
Software	PHP 7.4
	MySQL
	HTML5, CSS3, JavaScript
	Apache HTTP Server
	Visual Studio Code
	Git
	Correo institucional
Herramientas de apoyo	draw.io
	MySQL Workbench
	Microsoft Word / PDF
	Formularios

3.0 RESULTADOS

El desarrollo iterativo permitió implementar un sistema robusto y modular, con las siguientes funcionalidades validadas en el entorno universitario. Lo anterior parte de una situación común que las instituciones educativas de nivel superior de control estatal inicien con programas educativos y recursos limitados en gran parte de los casos en México. En este caso se presenta una opción de mejora significativa después de valorar sistemas comerciales y compara con el desarrollo de un sistema propio de la institución con la participación de la comunidad universitaria.

Para el desarrollo del sistema se desarrollaron cada un una de las etapas como se estableció en la metodología

3.1. Concepto inicial

Se identificó la necesidad de optimizar la gestión de información médica en el servicio de enfermería. A través de entrevistas y análisis de procesos existentes, se establecieron los requerimientos básicos del sistema, como el registro de pacientes, el control de consultas y la generación de reportes.

3.2. Diseño e implementación del prototipo inicial

Se desarrolló una primera versión funcional del sistema utilizando tecnologías web. Esta versión incluía los módulos esenciales definidos en el diagnóstico inicial, tales como el formulario de ingreso de pacientes y el módulo de autenticación de usuarios.

3.3. Refinamiento del prototipo

A través de pruebas con usuarios reales —principalmente personal de enfermería y administrativos— se recopilaron observaciones sobre usabilidad, comprensión de la interfaz y funcionalidad del sistema. En cada ciclo iterativo, se realizaron ajustes y mejoras hasta alcanzar una versión estable y aceptada por los usuarios clave.

3.4. Completamiento y entrega del prototipo

Finalmente, se consolidaron todos los módulos, se realizó una revisión técnica completa del sistema y se documentó su uso (Fig. 2). El prototipo final cumplió con los requerimientos establecidos y se encuentra listo para ser implementado en el entorno operativo.

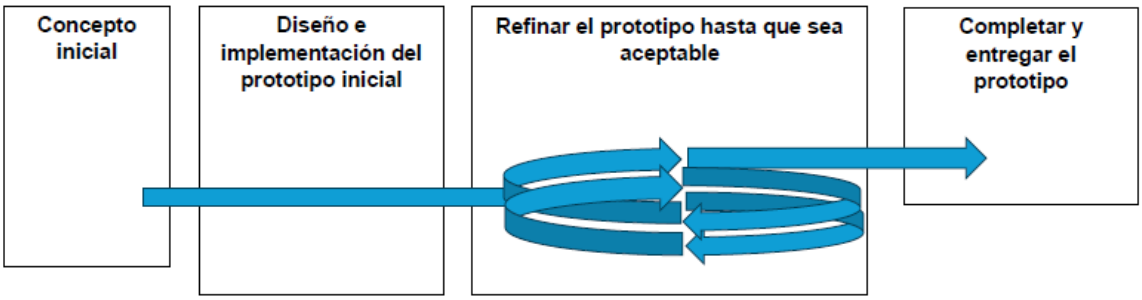
Concepto inicial
Diseño e implementación del prototipo inicial
Refinar el prototipo hasta que sea aceptable
Completar y entregar el prototipo

Figura 2. Modelo de protótipo evolutivo.

Para poder observar las funciones de los recursos se presenta a continuación la tabla 2.

Tabla 2.

Funciones de los recursos dentro del proyecto desarrollado

Recurso	Función o uso en el proyecto
Laptop/PC	Desarrollo, pruebas y documentación del sistema
Servidor local	Alojamiento del sistema en entorno de pruebas
Red institucional	Conexión entre cliente y servidor durante validaciones
PHP 7.4	Lógica del sistema y conexión con base de datos
MySQL	Gestión de datos (pacientes, usuarios, consultas, reportes)
HTML5, CSS3, JavaScript	Diseño y funcionalidad de la interfaz web
Apache HTTP Server	Servidor web en pruebas locales
Visual Studio Code	Edición del código y soporte de extensiones
Git	Control de versiones durante el desarrollo iterativo
Correo institucional	Módulo de recuperación de contraseña
draw.io	Diagramas de flujo, arquitectura y casos de uso
MySQL Workbench	Modelado visual de base de datos
Microsoft Word / PDF	Redacción de documentación técnica y académica
Formularios	Encuestas de validación y retroalimentación de usuarios

Después de identificar las funciones del proceso, se presentan los resultados de la aplicación, la cual fue diseñada en específico de acuerdo a los casos y necesidades del servicio de enfermería, lo cual permitió desarrollar un sistema único y funcional, aprovechando el talento de estudiantes, personal de enfermería, usuarios, docentes y Directivos.

Resultados alcanzados.

- Registro clínico completo con información médica, antecedentes, datos académicos y contacto de emergencia, se capturan en el sistema como se aprecia en la figura 3.

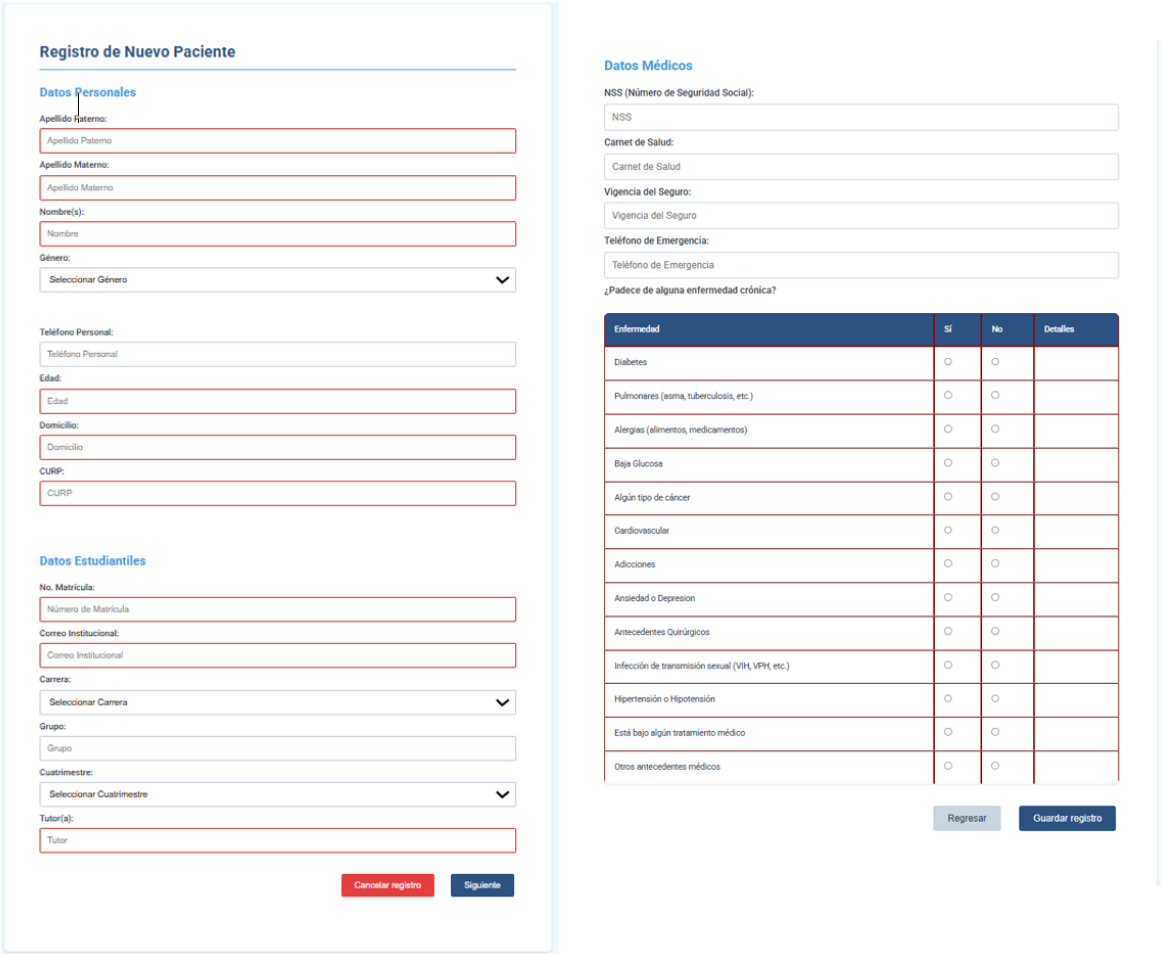

Figura 3. Registro clínico.

- Módulo de signos vitales (figura 4), que permite ingresar y consultar parámetros como presión arterial, frecuencia cardíaca y temperatura en tiempo real.

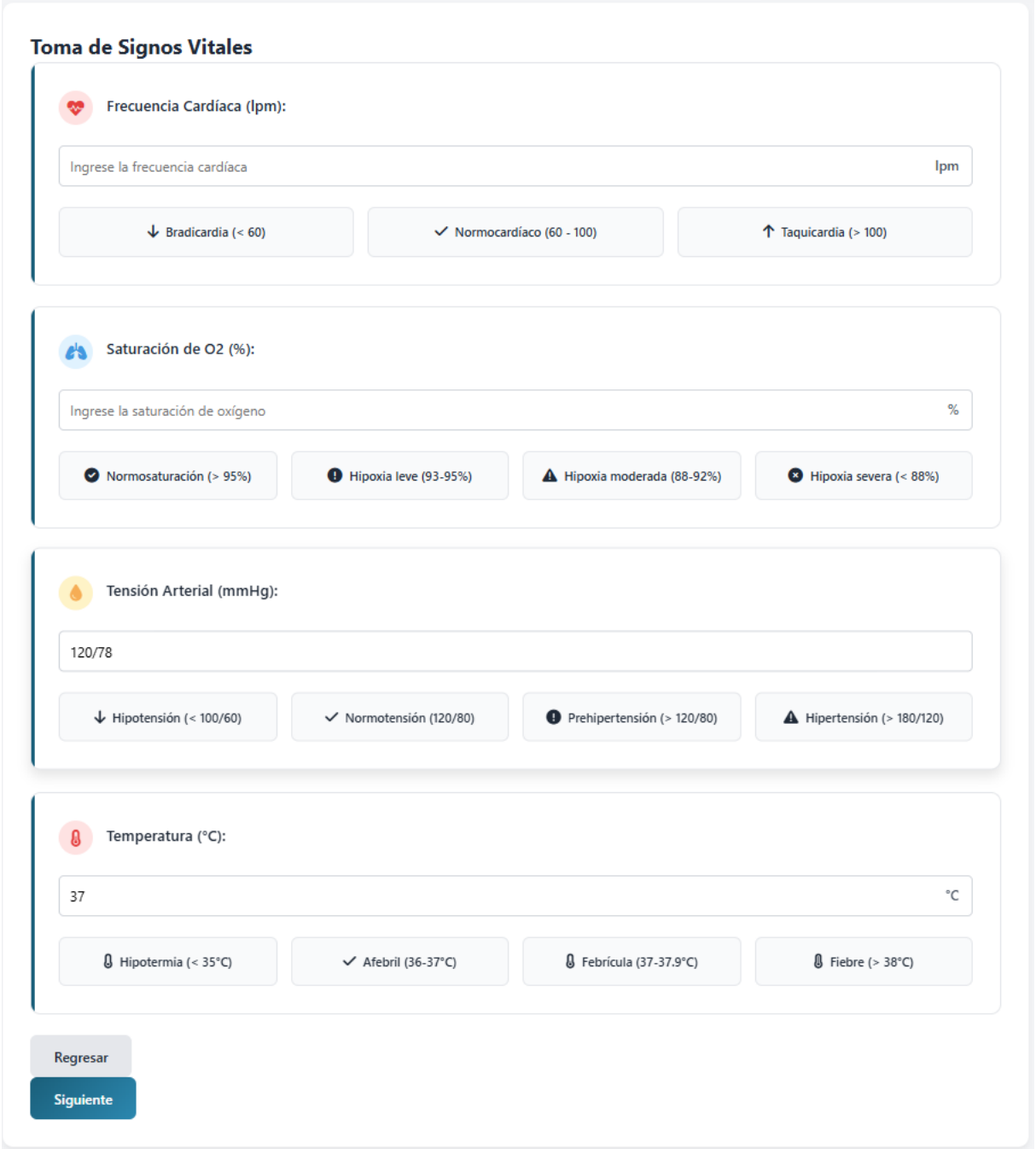

Figura 4. Toma de signos.

- Historial de consultas médicas accesible por cada paciente registrado, con campos editables y validación de datos (ver figura 5).

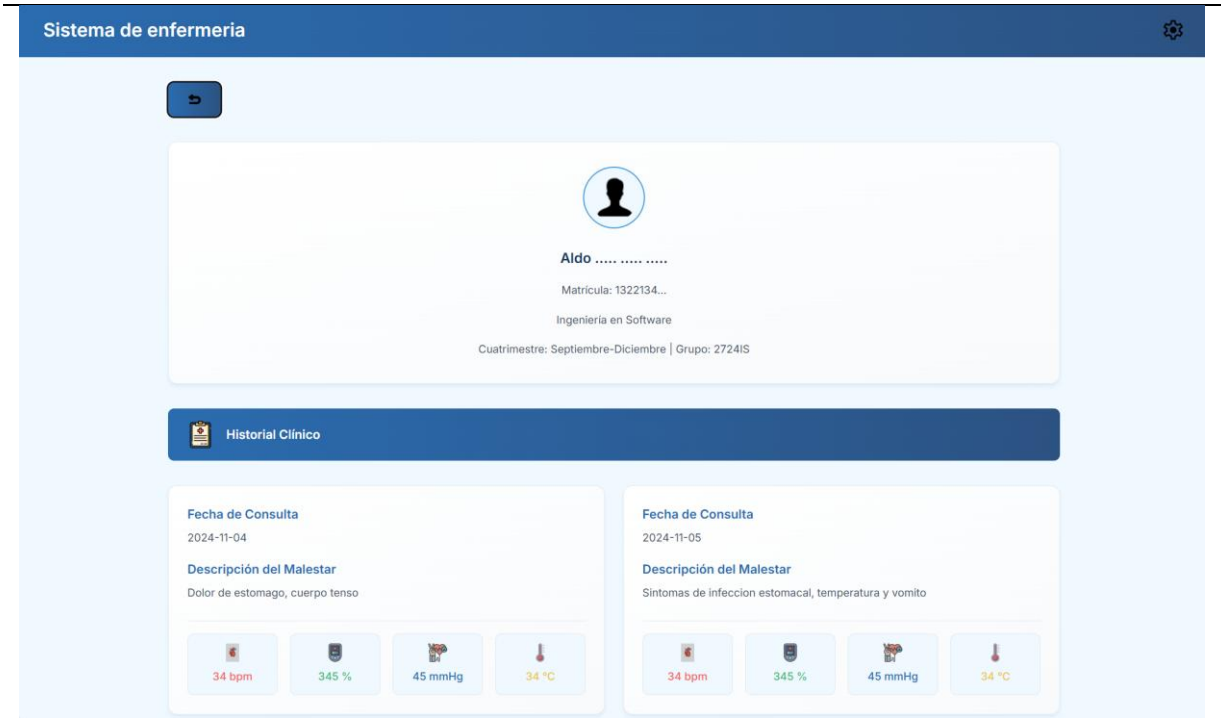

Figura 5. Historial de consultas.

- Sistema de autenticación del área y recuperación de contraseña por correo electrónico institucional (ver figura 6).

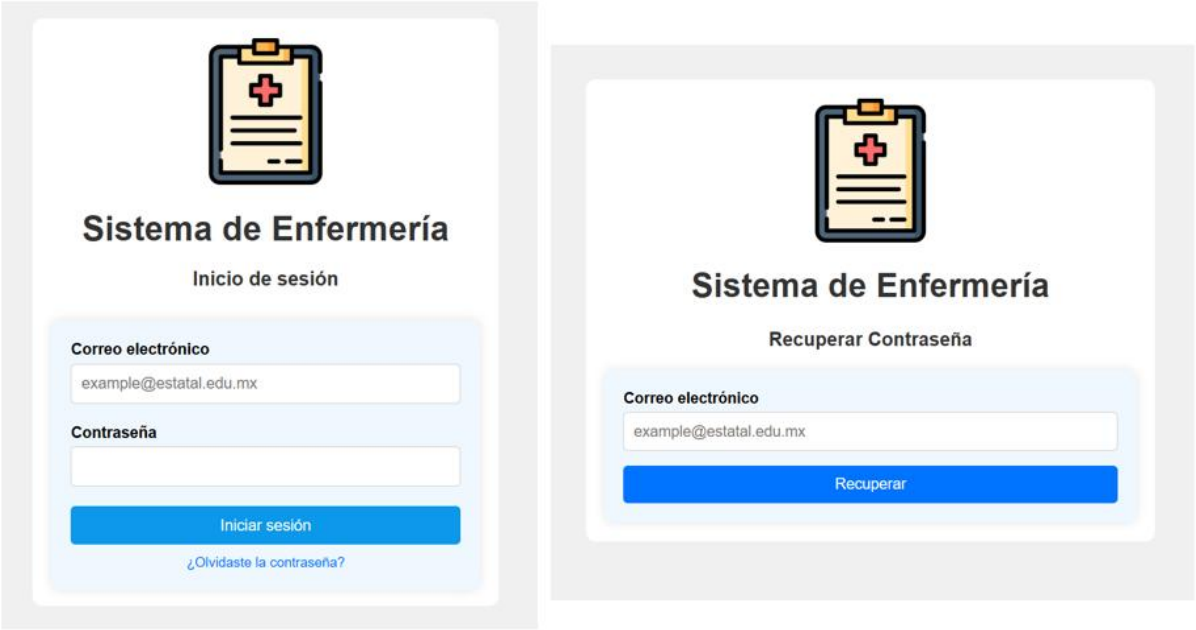

Figura 6. Acceso con autentificación.

Durante las pruebas finales, se observó una reducción del 60% en los errores de duplicación de registros y una mejora del 40% en el tiempo promedio de atención al paciente, según los reportes de control de pruebas como se aprecia en la figura 7.

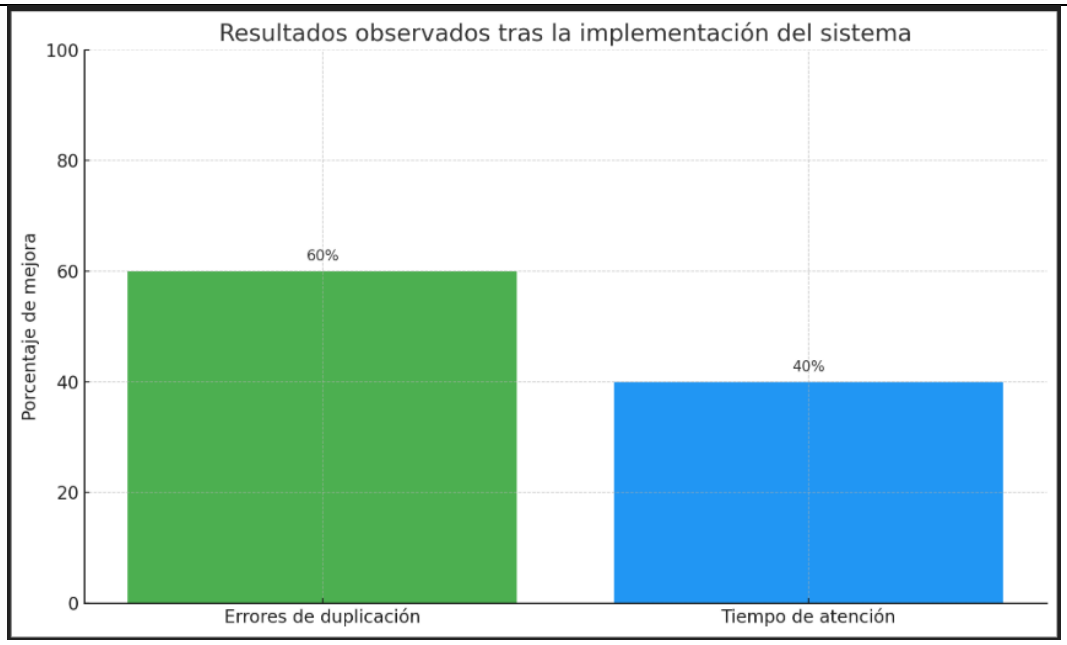

Figura 7. Porcentaje de mejora con el sistema de gestión de información.

4.0 DISCUSIÓN

La implementación del sistema de gestión de información en enfermería ha demostrado mejoras significativas en la eficiencia operativa y la calidad del cuidado. Estos hallazgos se alinean con lo señalado por García-Salas y Porras-Roque, quienes destacan que la digitalización de los registros clínicos y el uso adecuado de plataformas tecnológicas optimizan la documentación, fortalecen la seguridad del paciente y mejoran la calidad del cuidado en entornos clínicos [9].

El enfoque de prototipado evolutivo permitió una adaptación continua del sistema a las necesidades específicas del personal de enfermería. De acuerdo a Molina y colaboradores, este método es particularmente eficaz en el desarrollo de sistemas de información en salud porque promueve la participación de los usuarios finales durante todo el proceso de diseño, lo que asegura que las funcionalidades desarrolladas respondan a requerimientos reales y cambiantes. Además, el prototipado evolutivo facilita la incorporación incremental de módulos como el registro de pacientes y la generación de reportes clínicos, lo que mejora la aceptación y usabilidad del sistema en unidades clínicas [10].

Además, la incorporación de tecnologías móviles y herramientas digitales ha potenciado significativamente la capacidad del personal de enfermería para tomar decisiones clínicas informadas. Camila Santana y colaboradores destacan que estas tecnologías facilitan una mejor documentación y seguimiento continuo de los pacientes, lo cual contribuye a una atención más precisa y oportuna. El uso de dispositivos móviles permite acceder rápidamente a la información clínica, realizar registros en tiempo real y consultar protocolos, fortaleciendo así la calidad y seguridad en los procesos asistenciales [11].

Como se puede observar los resultados concuerdan con los trabajos de otros autores, por lo que el proyecto es congruente, viable y genera resultados valiosos en los sistemas de información de salud de las universidades estatales los cuales permitan que sean adaptables, eficientes y centrados en el usuario, para mejorar la atención al paciente y optimizar los recursos disponibles.

Conclusiones

El desarrollo del sistema de gestión de información en el área de enfermería, basado en la metodología de prototipado evolutivo, ha demostrado ser una solución viable y eficaz para enfrentar los desafíos derivados de los procesos manuales tradicionales en instituciones educativas de nivel superior. La implementación progresiva del prototipo permitió identificar de forma temprana los requerimientos reales del personal de enfermería, y adaptar el sistema a sus necesidades mediante ciclos iterativos de mejora.

Los resultados obtenidos indican que el sistema no solo optimiza el registro y consulta de datos clínicos y administrativos, sino que también mejora la trazabilidad de la atención médica, reduce la duplicidad de información y fortalece la toma de decisiones clínicas. Además, su estructura modular y su desarrollo con tecnologías de código abierto garantizan escalabilidad, sostenibilidad y bajo costo de mantenimiento.

Este trabajo contribuye al fortalecimiento de la gestión digital en servicios de salud universitarios y sienta las bases para futuras ampliaciones, como la incorporación de alertas automatizadas, conexión con sistemas externos o adaptación a plataformas móviles. La participación del personal de salud en el proceso de diseño fue clave para lograr una herramienta funcional, segura y centrada en el usuario.

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FORCE FUNCTION AS AN EFFECTIVE TOOL FOR BUILDING PROTECTION OF ELECTRICAL NETWORKS AND ELECTRIC MOTORS

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Abstract

At present, different parameters are also used to construct various protections, such as the effective value of the current, the Joule integral, the inverse sequence current, the reactive and active power. This makes it difficult to combine all the protections of power grids in one device. In order to concentrate all types of protections in one device, namely, in a switch, it is proposed to use a new parameter. Such a parameter is the sum of the squares of the instantaneous values of the currents of the three phases. The dependence of the change with time of the specified sum of the squares of the currents is denoted as the force function. The article substantiates the possibility of analyzing the nature of the power function for the construction of virtually all types of protection of electric networks, as well as for the thermal protection of electric motors. When implementing thermal protection of electric motors, the analysis of the force function allows you to use the windings themselves as sensors for the temperature of the windings of electric motors.

As for the protection of electrical networks, the analysis of the force function in transient mode allows you to reliably identify the starting current of electric motors. Interlocking the tripping of protection against the specified current increases the reliability of protection of networks against short-circuit currents, since this implements protection against remote short-circuit current and redundancy of the failure of the feeder circuit breaker by the input one.

Steady-state force function analysis allows you to implement protection against neutral wire breakage and the resulting overvoltages.

To build these protections, only information from current sensors is sufficient, so they can be combined with current protections in the circuit breaker trip. This makes it possible to abandon the use of other protection devices and thereby significantly reduce both the size and the cost of the entire power grid protection system.

Keywords: Force function, protection, power grids, electric motors

1. Introduction

1.1 The state of the problem of building defenses

At present, the analysis of different parameters is used to construct various types of protection of electric motors (ED) and electrical networks (EN). For example, the analysis of the effective values of phase currents I_f is used to construct current protections. Such protections are available in circuit breakers. Other parameters are used to construct more complex protections. For example, to construct protection against remote short-circuit currents (SC) and to reserve the failures of feeder circuit breakers [1], the analysis of active and reactive components of the current, as well as the power of the direct sequence. To construct a protection against the break of the neutral wire (N-wire), the analysis of the value of the reverse sequence current - current - has recently been used - I_0 .

According to the analysis given in [2], the current analysis I_0 is carried out, for example, in the БМРЗ - 102 units (R&D Center "Mechatronics") and the MiCOM P126 relay (Schneider Electric). All these protections are formed not in circuit breakers, but in separate devices

From the analysis, it follows that, in general, the expansion of the list of EE protections requires a significant increase in the infrastructure of these networks and an increase in the cost of the entire protection system.

As for the thermal protection of ED operating in the mode of frequent start-ups, the thermal protection according to the integral $Q = I_f^2 t$ analysis is very inertial, so it is replaced by current temporary protection [3]. In such protection, the ED is switched off when the phase current is exceeded, which allows for a quick reactivation of the ED. But to ensure thermal protection, it is necessary to directly measure the temperature of the ED windings with special temperature sensors, which must be mounted in the stator winding of the ED. It is quite obvious that when upgrading equipment (coal miners, etc.) in order to increase productivity, it is necessary to replace rather expensive, but without ED temperature sensors

1.2 Objectives of the work and the article

One of the goals of the work presented in this article is to develop such methods for constructing EN protections that make it possible to concentrate all protections in the circuit breaker. Current protections in circuit breakers are built on the basis of the analysis of information from current sensors only. This means that other, more complex protections should be based on the analysis of information from current sensors only. Therefore, the task was to develop methods for constructing protections based on the analysis of the force function – the dependence of the change in the current the time of the sum of the squares of the instantaneous values of the current $\boldsymbol{i_f^2}$ is a function $\boldsymbol{F_s(t)}$. The latter, in fact, is a more convenient for analysis "packing" of instantaneous current values, which are used in current protection to determine the effective values of phase currents.

The purpose of the work was also to develop a method for measuring the temperature of the ED windings at each next start by using the windings themselves

as temperature sensors. The basis of this method should be the analysis of the forcefunction.

In general, the purpose of the work was to substantiate the fact that in the construction of protections, it is expedient, in addition to classical parameters, to use such a parameter as the sum of squares of phase currents. And the **force** function, as a dependence of the change in the specified amount of currents over time, can be an effective tool for creating new protections for electric motors and electrical networks. After all, the analysis of the nature of the **force** function in steady-state and transient modes makes it possible to build all types of network protections and combine them with current protections in the circuit breaker.

2. Main results of the work

The construction of all EE and ED defenses is based on the analysis of the power function $F_s(t)$, the expression of which in general is as follows:

$$F_s(t) = [i_a(t)]^2 + [i_b(t)]^2 + [i_c(t)]^2 \quad (1)$$

where $i_a(t)$, $i_b(t)$ и $i_c(t)$, and are the dependencies of the change in time of the phase currents. Let us consider the nature of the force function in the transient and steady-state modes for the case when the modules of the phase currents are the same in magnitude ($I_a = I_b = I_c = I_f$) and the angles between the phase current vectors are also the same.

The transient mode of the force function is the mode of occurrence of network disturbance currents. After introducing into equation (1) the well-known expressions of the change in phase currents in the event of a disturbance of the electric network, we obtain the following expression for the force function in the transient mode:

$$F_s(t) = 3I_f^2(1 - 2e^{-t/\tau}\cos\omega t + e^{-2t/\tau}) \quad (2),$$

where τ is the electromagnetic constant of time.

The steady-state mode of the force function is understood as a mode in which there is no disturbance of the network. Earlier, expression (1) was given for the force function, as the sum of the time dependencies of the squares of phase currents $F_s(t)$. After introducing into equation (1) the well-known expressions of the change of phase currents in the steady-state regime, we obtain the following expression for the force function $F_s(t)$ in the steady-state mode:

$$F_s(t) = 3I_f^2 + \left[I_f^2 \cos 2\omega t + I_f^2 \cos 2(\omega t + 2\pi/3) + I_f^2 \cos 2(\omega t - 2\pi/3)\right] \quad (3)$$

Let us consider the features of the nature of the force function in the transitional and steady-state modes and analyze the possibility of using these features to build defenses.

2.1 Transient Force Function

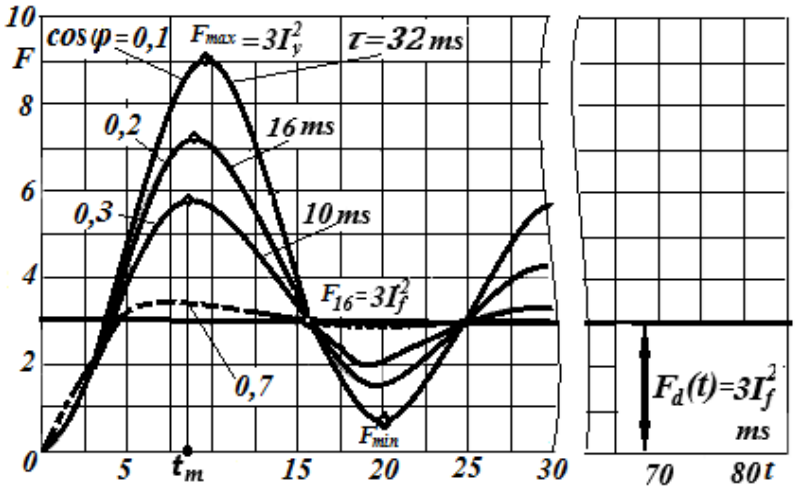

Fig.1 Graphs of the force function at different cosφ and τ values

As follows from expression (2), the nature of the force function $F_s(t)$ does not depend on the moment of the disturbance of the network, but depends on the value of the electromagnetic constant of time τ or *on cosφ.* Figure 1 shows the graphs of the force function for networks with different values cosφ *(*or *τ).* Let's analyze the features of the charts and note their "fiducial" points, which are important for building defenses. As can be seen from the graphs of Fig.1, the function $F_s(t)$ eventually reaches first its maximum value F_{max} and then its minimum value F_{min}. These extreme values of the function are the first two "reference" points. The third "reference" point is the value of the function $F_s(t)$ at a time 16 ms after the occurrence of the disturbance current – the value of - F_{16} .

The peculiarity of this "reference" point is that regardless of the value *of cosφ (τ),* the value of the force function F_{16} , with a small error, is equal to the value proportional to the square of the value of the steady-state value of the phase current I_f^2. The value F_{16} is determined by the following expression:

$$F_{16} \sim 3I_f^2 \quad (4)$$

The fourth "reference" point is the moment when the function $F_s(t)$ reaches its maximum value - the moment of time t_m .

Now let's consider how "fiducial" points can be used for various defenses.

2.1.1. Protection against remote short circuits, backup of feeder failures and thermal protection of ED.

The essence of the construction of protection against the identification of remote short-circuits is to identify the start of the ED and to block the operation of the protection against the inrush current of the ED. Identification of inrush currents is carried out by the value of *cosφ*, the value of which is within *cosφ = (0.2÷0.4),* while in the case of remote short-circuits, the value of *cosφ = (0.7÷0.8).*

When implementing reservation, the problem is that the total value of inrush currents in several feeders can be greater than the value of the short-circuit current in one of the feeders. Therefore, the protection in the input apparatus must identify the inrush currents of the ED and block the tripping of the protection.

2.1.2. Thermal protection of electric motors in case of frequent

When constructing thermal protection of ED with frequent farts, it is not necessary to identify the type of network disturbance. It is necessary to estimate the change in the time constant, which characterizes the value of the change in the winding temperature at each successive start of the ED.

2.1.3 Summary of the use of force function analysis in transient mode

Thus, in order to construct these defenses, it is necessary to solve the problem of quickly determining the value of *cosφ (*or *τ).* The need for a quick determination of cosφ (or τ) values is due to the fact that with an increase in the rate of ED, these values change.

As follows from the graphs of Fig.1, the values of reference points F_{max} and F_{min} essentially depend on the values *cosφ* and *τ.* For example, when measuring *cosφ* from *cosφ=0.3* (ED start) to *cosφ=0.7* (short circuit on the cable line), the ratio value . $K_F = F_{max}/F_{min}$ changes from value $K_F = 3$ to value, $K_F = 1.2$,i.e. by 2.5 times.

When the ED windings are heated and *τ* changes from τ=*16 ms* (20°C) to *τ=10 ms (120°C),* the value of the ratio $K_F = F_{max}/F_{min}$changes from value $K_f = 5$to value , $K_F = 3I_f$ i.e. by a factor of 1.8. It should be noted that the value of the phase current at a temperature change of 20°C to 120°C will be commensurate with the current measurement error.

Thus, the significance of the value K_F for determining the change in the winding temperature is quite high and allows to ensure the necessary reliability of the thermal protection of the ED.

However, in the case of EE protection, high reliability of inrush current identification is possible provided that there can only be three-phase symmetrical short-circuits in the network. In two-phase or asymmetrical short-circuits, the ratios F_{max} and F_{min} , in principle, can coincide with the values typical for inrush currents. Therefore, additional measures are needed to improve the reliability of inrush current identificationby using the analysis of all "reference" points of the force function.

The analysis of the force function $F_s(t)$ into extremes F_{max} showed that the moment of time when the function reaches its maximum value is reached at the same time at which the shock current would arise I_y in one of the phases. This means that the magnitude F_{max} can be expressed in terms of the magnitude of the shock current : I_y by the following expression

$$F_{max} = 3I_y^2 \quad (5)$$

Since the value of the "reference" point F_{16} is expressed in terms of the value of the steady state value of the phase current I_f by equation (4), the expression for the impact coefficient K_y can be represented by the following expression:

$$K_y = \sqrt{F_{max}/F_{16}} \quad (6)$$

Thus, the second method for determining the value of *cosφ* is the analysis of the ratio of the "reference" points of the force function F_{max} and the F_{16} .

The third method for determining the value of *cosφ* involves the use of the dependence of *cosφ* on the value $t_{max}of$.

Figure 2 shows the dependence *cosφ=f(*t_{max}*),* as well as the dependencies *cosφ=f(* K_F*)* и $cos\varphi = f(K_y)$ necessary to determine the value of *cosφ* from the values K_F and K_y .

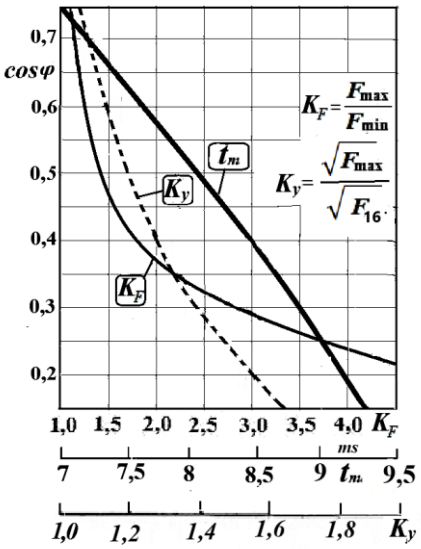

Fig.2 Dependences of cosφ on quantities K_F; t_{max} and K_y

Determination of the cosφ value using three methods provides high reliability of identification of the inrush current ED.

3. Steady-state force function

It follows from expression (3) for the force function that the dependence $F_{sa}(t)$contains a constant $F_{sd}(t)$ and a variable component $F_{sa}(t)$. The expression for a constant component looks like this:

$$F_{sd}(t) = \mathbf{3}I_f^2 \quad (7)$$

The component variable is expressed by the following equation:

$$F_{sa}(t) = \left[I_f^2 \cos 2\omega t + I_f^2 \cos 2(\omega t - 2\pi/3) + I_f^2 \cos 2(\omega t + 2\pi/3)\right] \quad (8)$$

3.1 Protection against neutral wire breakage and resulting overvoltages

Let us consider how the analysis of the force function in the steady-state mode can be used to construct a protection against the breakage of the N-wire.

For a fully symmetrical current system in which the modules of the phase currents are the same and equal I_f and the angles between the phase current vectors are the same, the value of the alternating component $F_{sa}(t)$ will be zero. In a real three-phase network with an N-wire, the current system is generally not symmetrical. If there is no open N–wires, then the angles between the current vectors are almost the same. But the modules of phase currents will be different in size. This means that for a real network, there are both constant and variable components in the force function.

Therefore, it is advisable to analyze the force function not of a real current system, but of a transformed system in which the moduli of the phase currents are made identical ($I_{a=}\ I_b = I_c = I_f$) by means of equalization coefficients. For such a transformed system of currents, the variable component of the force function $F'_{sa}(t)$ will be equal to zero. This means that the force function $F'_s(t)$ in its composition will have only a constant component $F'_{sd}(t) = \mathbf{3}I_f^2$. It follows that by the nature of the force function of the transformed system of currents, it is possible to estimate the state of the N-wire. If the force function contains only a constant component, then it indicates that $F'_{sd}(t)$ there is no break in the N-wire.

Let us consider how the nature of the force function $F'_s(t)$ of the transformed current system will change in the event of an N - wire break. When the angles between the phase current vectors are no longer the same, the variable component will no longer be equal to zero. This means that both $F'_s(t)$ constant $F'_{sd}(t)$ and alternating $F'_{sa}(t)$ components will be present in the force function.

3.2 Summary of force function analysis

By the nature of the force function of the transformed system of currents, it is possible to determine the fact of a break in the N-wire. At the same time, by the value of the variable component, F'_{sa} (t) it is possible to determine the value of the resulting overvoltage ΔU_f .

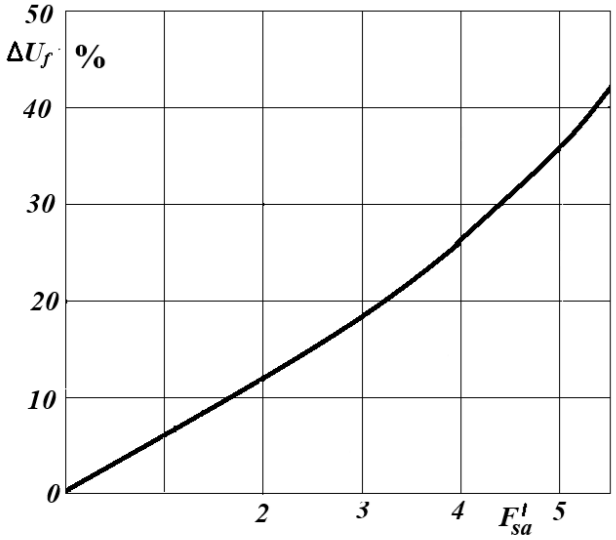

Fig.3 Dependence of the value of overvoltage ΔU on the value of F'_{sa}

Fig.3 shows the dependence of the ΔU_f overvoltage value on the effective value of the variable component F'_{sa} based on the results of a machine experiment. The value F'_{sa} is expressed in relative units to the value of the constant component. F'_{sd} .

4. Methods of using the analysis of the force function for the construction of defenses

4.1 Analysis of the force function in the transient mode

From the above results of the analysis of the features of the force function in the transient and steady-state modes, it follows that on the basis of the analysis of the force function, various types of defenses can be built. A block diagram of the use of force function analysis methods for constructing EN and ED defenses is shown in Fig. 4.

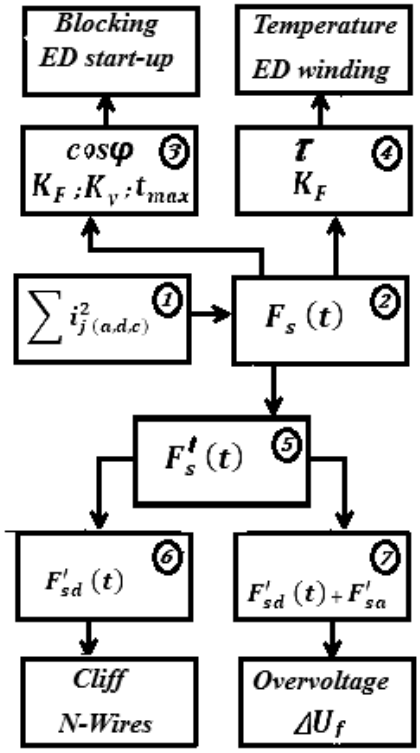

Fig. 4 Flow Chart of Applying Force Function Analysis to Construction protection of power grids and electric motors

In module 1, discrete values of currents in phases of quantities i_{ja}; i_{jab} $i_{jc}$are monitored, during the time of one period of current change. In the same modulus 1, the sum of squares of discrete values of currents and phases $\sum i^2_{j(a,b,c)}$. is formed.

In modulus 2, the sum of the squares of the current values $\sum i^2_{j(a,b,c)}$ forms the force function $F_s(t)$.

In module 3, when constructing EE protection from the analysis of the nature of the force function, its "reference" points F_{max} ; F_{min} ; F_{16} и t_{max} are determined; and . using the values of the "fiducial" points, the values of the coefficients $K_F = F_{max}/F_{min}$ and, $K_y = \sqrt{F_{max}/F_{16}}$. Then, from the dependencies $cos\varphi$=*f*(K_F) $cos\varphi = f(K_y)$and $cos\varphi$=*f*(t_{max}) determine the value $cos\varphi$. If the $cos\varphi$ same result is obtained for all 3 methods of determining the value $cos\varphi$. , then this means that the nature of the force function corresponds to the nature of the force function at either ED or three-phase short circuit on the line. If the value $cos\varphi$ =*(0.2÷0.3),* and the value of the phase current $I_f \leq$*(5÷7)* $I_r$where I_r – operating current of the network, then the disturbance current of the network is considered to be the starting current of the ED. In this case, a signal is generated in module 3 to block protection against short-circuit currents.

In the formation of the thermal protection of the ED during frequent starts, the value of the coefficient is determined (modulus 4) K_F and, from the dependence τ = *f*(K_F) the value of the winding time constant τ is determined at each successive start of the ED, which characterizes the temperature of the ED windings.

4.2 Analysis of the force function in the steady-state mode

In Module 5, the initial phase current system $i'_a = f(t)$, $i'_b = f(t)$ *u* $i'_c = f(t)$ made by means of equalization coefficients to be the converted current current system $i'_a = f(t)$, $i'_b = f(t)$ *u* $i'_c = f(t)$. In the same module, 5 form the force function $F'_s(t)$.

If the force function $F'_s(t)$ contains only the constant of the component $F'_s(t) = F'_{sd}(t)$, then in module 6 the information "Break N-wire is no formed''.

If the force function $F'_s(t)$ includes both constant and variable components - $F'_s(t) = F'_{sd}(t) + F'_{sa}(t)$, then in module 7, depending on the $\Delta U_f = f(F'_{sa})$, the value of overvoltage is determined ΔU_f at the exhaust clamps of the protective apparatus.

5. Key findings

The expediency of using the analysis of the sum of squares of instantaneous values of currents of three phases for the construction of protection of electric networks and electric motors is substantiated. Instead of a number of classical parameters, with the help of the analysis of which various protections are constructed, it is proposed to use one parameter for all protections in the form of a sum of squares of current values. This parameter is essentially a convenient "packet" of instantaneous values of phase currents for analysis. Therefore, various types of protections can be built on the basis of the analysis of information from current sensors

only. These advantages of the proposed parameter are due to the fact that the dependence of its change with time, designated as the force function, has a number of features that are useful for the construction of defenses.

First, in the steady state with a symmetrical load, the value of the force function is a constant value. This makes it possible to monitor the condition of the neutral wire and record the fact of its breakage and the amount of the resulting overvoltage in the network.

Secondly, as a consequence of the constancy of the quantity in the steady-state regime, in the transient mode, the nature of the force function depends only on the value of the electromagnetic constant of time τ. At the same time, the peculiarity of the nature of the force function allows the determination of cosφ according to 3 methods, which ensures the reliability of identification of the inrush currents of the ED to block the tripping of the current protection against the inrush currents of the ED. Due to this, protection against currents of remote short-circuits is implemented. Due to this, protection against currents of remote short-circuits is implemented. Blocking the tripping of protection against inrush currents makes it possible to perform the function of redundancy of feeder circuit breakers by input devices.

The ability to control the value τ, and therefore the temperature of the ED windings, at each next start of the ED, allows the windings themselves to be used in the temperature sensors when building the ED protection operating at frequent starts.

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INCREASING THE EFFICIENCY OF PSYCHOLOGICAL SUPPORT IN CRISIS SITUATIONS USING AN INFORMATION SYSTEM BASED ON GENERATIVE ARTIFICIAL INTELLIGENCE

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Abstract

One of the pressing problems under conditions of prolonged exposure to stress factors is the implementation of effective online psychological support services. This article investigates the use of generative artificial intelligence (GAI) for creating an information system designed to support individuals in difficult life situations (providing self-help and self-reflection recommendations) as well as to assist the professional activities of psychologists. The proposed system generates knowledge-based recommendations using semantic content retrieval implemented with a domain-adapted LLaMA-based LLM with Retrieval-Augmented Generation architecture and context-aware personalization (users' emotional state, interactions history, and situational factors). The implemented approach combines semantic text generalization, empathetic formulation of recommendations, and access to a psychological knowledge base online. This significantly increases the accessibility and speed of psychological assistance. Experimental testing of the prototype, evaluated using Precision@k, Recall@k, and MRR metrics, demonstrated high relevance, completeness, and quality of recommendation ranking. A sociological survey of potential users and professionals confirmed the relevance and feasibility of employing the developed online service in crisis situations.

Keywords: psychological support, generative artificial intelligence, large language model, retrieval-augmented generation, knowledge-based filtering, semantic embedding, natural language processing.

1. Introduction and Related Work

Modern social and security challenges associated with martial law, mass traumatic events, and increased psychological stress on the population lead to a growing need for accessible and scalable means of psychological support. The prolonged impact of stress factors caused by hostilities is accompanied by large-scale human losses, the death of loved ones, the destruction of housing infrastructure, forced displacement, regular air-raid alerts, shelling, and other dangerous factors. This leads to persistent psychoemotional stress and depletion of individuals' adaptive potential.

Traditional forms of psychological assistance are not always able to respond promptly to increasing demand, especially under crisis conditions, which necessitates expanding the use of online services [1]. Existing research in the field of psychological care demonstrates the effective use of online platforms and chatbots for diagnosis, consultations with specialists, social support, and enhancing patients' mental resilience [2, 3]. New opportunities for their development are provided by rapid advances in artificial intelligence (AI) technologies, particularly natural language processing (NLP) methods and large language models (LLMs) as representatives of generative artificial intelligence (GAI) [2]. Current research shows that use of LLMs enables the analysis of a person's mental state through semantic interpretation of natural language, identification of intentions, mood, emotional markers, and cognitive patterns, as well as the generation of personalized dialog recommendations that take into the context of interactions and individual characteristics of the user [3-7].

However, despite the significant potential of LLMs, they have several limitations, in particular their knowledge is constrained by pre-training data and their tendency to hallucinate, which requires additional mechanisms for result validation and knowledge control. Their unpredictable nature can lead to erroneous, potentially harmful recommendations and unexpected negative consequences [8]. There are also risks such as privacy breaches, biases, and security issues [9]. Unlike general-purpose dialog agents, virtual psychologists require specialized training or fine-tuning of LLMs and multi-level filtering of responses that takes into account evidence-based psychological support protocols and the need to refer users to a specialist in critical cases. Addressing these challenges requires the development of information systems that implement ethical, transparent, and controlled approaches aimed at reducing the risks of incorrect or unsupported advice and combining AI with professional psychological support. A survey conducted among potential users and professional psychologists confirmed the demand for such intelligent psychological support services (fig. 1).

An effective approach to improving the reliability of generative models is their integration with the Retrieval-Augmented Generation (RAG) architecture. Integrating LLMs with RAG provides access to a domain-specific knowledge base with semantic search prior to response generation, increasing the relevance, validity, and explainability of recommendations, reducing the risk of hallucinations, and enabling knowledge updates without retraining the model [10, 11]. However, the practical implementation of such an approach in the domain of psychological care remains insufficiently studied and requires further development.

The purpose of this article is to develop and research an information system for psychological support based on generative artificial intelligence models with integrated RAG architecture, designed to

provide prompt, accessible, and evidence-based recommendations for individuals in difficult life situations and for professional psychologists.

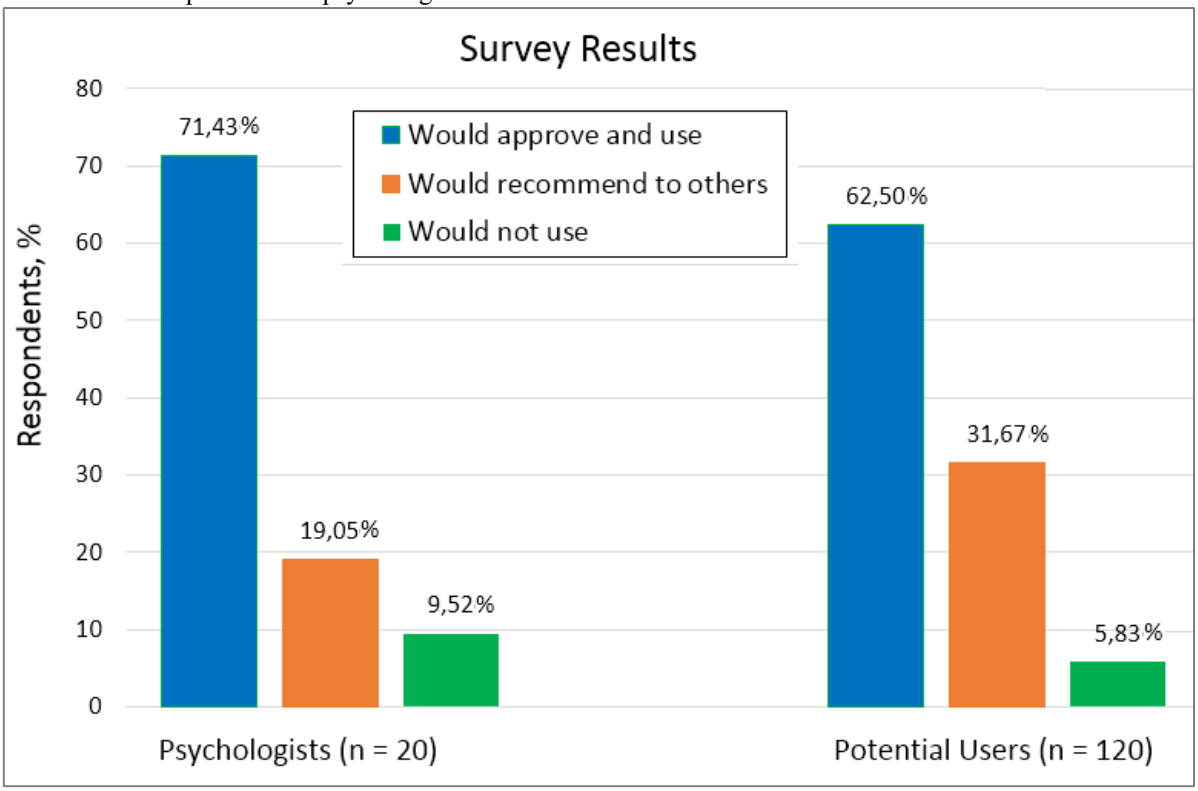

Figure 1. Assessment of User Needs for Online Psychological Support Systems

2. Information system architecture

The developed psychological support information system implements a multi-level modular architecture that provides a coordinated integration of generative language models, natural language processing methods, and infrastructure for data storage and synchronization. This approach allows for a clear delineation of the functional roles of system components, ensures scalability and controllability of recommendation generation, and supports the personalized nature of the recommendations.

1. *Client Level*. The client level is represented by a web interface designed for two user roles: individuals seeking psychological support and psychological specialists. The interface provides authentication, interaction session management, access to dialogue history, and role-based access to system functionality.

2. *Generative Level* (*LLM Level*). The generative level of the system is implemented using the large language models LLaMA and ChatGPT, which serve as tools for generating dialog responses and textual recommendations. Access to the generative services is provided through application programming interfaces (APIs), enabling interaction with the client application without requiring client-side computation.

The LLaMA model serves as the primary generative component for the semantic interpretation of user queries, conducting dialogue, and the generation of personalized recommendations. It is used without parameter modification (i.e., without fine-tuning), and its domain adaptation is achieved through integration with the Retrieval-Augmented Generation (RAG) architecture. The model operates as a private cloud service deployed within an on-premise infrastructure. Additionally, the system supports integration with ChatGPT via API as an alternative generative component for producing explanations or enriching response content. This ensures architectural flexibility and enables the use of models hosted in the public cloud.

3. *Domain-Specific Knowledge Access Level* (*Retrieval Level*). The knowledge access level implements a knowledge-based approach to recommendation generation and is responsible for the intelligent filtering of information. It is built using the LlamaIndex framework, which enables the indexing of professional textual sources (psychological literature, counseling techniques, support scenarios, and recommendation protocols), semantic retrieval of relevant fragments, and their integration into the response generation context within the RAG architecture. In the proposed implementation, RAG expands the model context by incorporating relevant fragments from the domain-specific knowledge repository prior to answer generation. This increases the relevance, validity, and controllability of recommendations and reduces the risk of unsupported or irrelevant advice in the provision of psychological support.

Contextual personalization of recommendations is achieved by taking into account the results of semantic retrieval, the history of previous interaction sessions, and the situational context of the user's request. This approach enables intelligent information filtering within the system’s recommendation logic.

A cloud-based NoSQL database built on the Firebase platform is used for real-time data storage, synchronization, and exchange. This component provides storage of dialogue history, access to a repository of professional information sources in JSON format, and support for complex queries and asynchronous interaction between users and psychologists. This contributes to the consistency of recommendations and the continuity of the psychological support process.

4. *Natural Language Processing Level* (*NLP Level*). The NLP level is implemented using the TextBlob library, which is based on NLTK and Pattern. The components of this level provide: preliminary analysis of user queries, text tokenization and linguistic normalization, extraction of linguistic and emotional features, sentiment analysis and emotion detection, post-processing of generated responses. The extracted features are used to assess the user's psycho-emotional state and serve as parameters for intelligent filtering in the formation of personalized recommendations.

After response generation, the post-processing and filtering stage performs semantic validation of the generated response with respect to the user's context-enriched query, safety and ethical filtering, role-based adaptation of the generated content, removal of redundant or potentially unsafe fragments, and formatting of the final response before it is delivered to the user.

The system architecture combines a private cloud generative service based on the LLaMA model (on-premise private cloud AI service) with a public cloud infrastructure for data storage and synchronization. This approach ensures a balance between confidentiality, control over data processing, and scalability. The overall interaction logic of the system components is presented in figure 2.

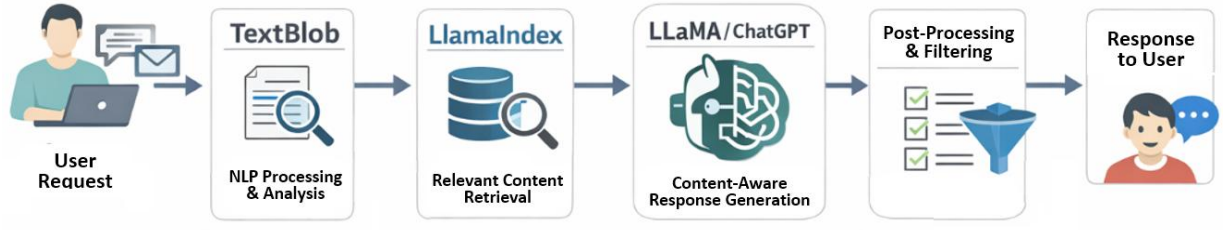

Figure 2. The generalized logic of component interaction

The proposed architecture integrates generative artificial intelligence with knowledge-based mechanisms for intelligent information filtering and provides a technological foundation for the experimental evaluation of the system in the field of psychological support.

3. Knowledge-Based Filtering with Semantic and Contextual Adaptation for Recommendation Generation

Information filtering in the system is implemented using a knowledge-based approach based on vector semantic representations of text, supplemented with contextual adaptation of the results. Personalized recommendations are generated by approximating a utility function:

$$f(u, i, c): U \times I \times C \to \mathcal{R}, \quad (1)$$

where $U = \{u_j \mid j = 1, \dots, m\}$ is the set of users, including the roles of patient and psychologist;

$I = \{i_l \mid l = 1, \dots, n\}$ is the set of information objects in the professional knowledge repository (therapeutic techniques, counseling scenarios, diagnostic approaches, psychoeducational materials, and self-help recommendations);

C is the set of contexts that includes, for each user $u \in U$, the user's role, the history of current and previous dialogues, and situational and emotional factors;

$\mathcal{R}$ is an ordered numerical space of utility values defined over the set of real numbers ($\mathcal{R} \subseteq \mathbb{R}$), whose ordering is used to rank information objects.

The value of the function $f(u_j, i_l, c_j)$ is interpreted as the predicted relevance of the information object i_l for the user u_j, given the user's context c_j.

Information objects $i \in I$, represented by a single semantic embedding in the knowledge base, are used to generate recommendations at different levels of abstraction. For psychologists, the system produces recommendations in the form of professional methods and counseling scenarios. For individuals seeking psychological support, the same knowledge is delivered as generalized guidance and self-help instructions that comply with ethical and informational constraints. This approach ensures the unity knowledge-based filtering regardless of the user's role.

In the proposed architecture, the user's context is directly incorporated into the process of generating the semantic representation of the query. The text query q of user u_j, interacting with the system, is concatenated with their context c_j:

$$q' = c_j \oplus q, \quad (2)$$

where $\oplus$ denotes the ordered concatenation of text sequences.

The context-enriched query q' and the information objects i from the knowledge base repository undergo preprocessing at the NLP level of the system (tokenization, lexical normalization of the text, and extraction of linguistic features), after which they are mapped into a shared high-dimensional semantic space of embeddings generated by the encoder of the LLaMA model:

$$e(q', c_j) \in \mathbb{R}^k, e(i_l) \in \mathbb{R}^k. \quad (3)$$

where $e(q', c_j)$ is the embedding vector of the context-enriched query q';

$e(i_l)$ is the embedding vector of the information object i_l, $l = 1, \dots, n$;

$\mathbb{R}^k$ is the k-dimensional real vector space, in which are presented semantic representations of text data.

The relevance of each information object $i_l \in I$ to the user u_j's query q' is defined as the proximity measure between the embedding vectors of the context-enriched query and the information object:

$$f(u_j, i_l, c_j) = sim(e(q', c_j), e(i_l)). \quad (4)$$

Before computing the proximity measures, the embedding vectors are normalized using L2 normalization:

$$\hat{e} = \frac{e}{\|e\|_2}, \quad (5)$$

where $\|e\|_2 = \sqrt{\sum_{t=1}^{k} e_t^2}$ is the euclidean norm of a vector.

This enables the computation of the cosine similarity measure as the scalar product of the embedding vectors:

$$sim(e(q', c_j), e(i_l)) = e(q', c_j) \cdot e(i_l). \quad (6)$$

After computing the utility function $f\left(u_j, i_l, c_{u_j}\right)$ for all objects $i_l \in I$ the objects are ranked in descending order of relevance, and those with the highest utility function values are selected. The resulting set of relevant information objects is used as the knowledge context in the retrieval-augmented generation (RAG) mechanism. The ChatGPT API is employed to generate textual responses based on the selected knowledge context**.**

Thus, the information system implements knowledge-based filtering with semantic and contextual adaptation for generating personalized recommendations. The context is modeled through an extended embedding-based query in a shared latent semantic space, consistent with the principles of modern RAG architectures. LLaMA provides the core functionality for semantic search and generation within a private cloud environment, while ChatGPT is used as an optional external generative component without interfering with the retrieval mechanism. The proposed approach enables semantically grounded, context-adaptive, and role-sensitive recommendation generation while minimizing lexical mismatch and excessive generalization.

4. Results and Discussion

The developed system is available online at any time, enabling the provision of initial psychological support outside face-to-face consultations and promoting continuity of interaction between the client and the psychologist. The software prototype of the system was developed as part of a master's thesis conducted under the supervision of the author. To begin working with the system web application, the user performs authentication, after which the main page is displayed (fig. 3).

After authentication, the user can submit queries and receive responses from the system in a dialogue format. The history of previous dialogues is stored and used as context for generating responses to subsequent user queries, which enables context-dependent personalization of recommendations.

At the stage of preliminary query processing, implemented at the Natural Language Processing level of the system architecture, text analysis is performed using polarity and subjectivity metrics. Polarity reflects the emotional tone of a message, whereas subjectivity characterizes the degree of personal or emotional evaluation expressed in the statement. The polarity value ranges from -1 to 1, where negative values correspond to negative emotional tone (-1 representing the most negative value), while positive values correspond to positive tone (1 representing the most positive value). The subjectivity score ranges from 0 to 1, where 0 corresponds to a completely objective statement and 1 indicates a fully subjective expression.

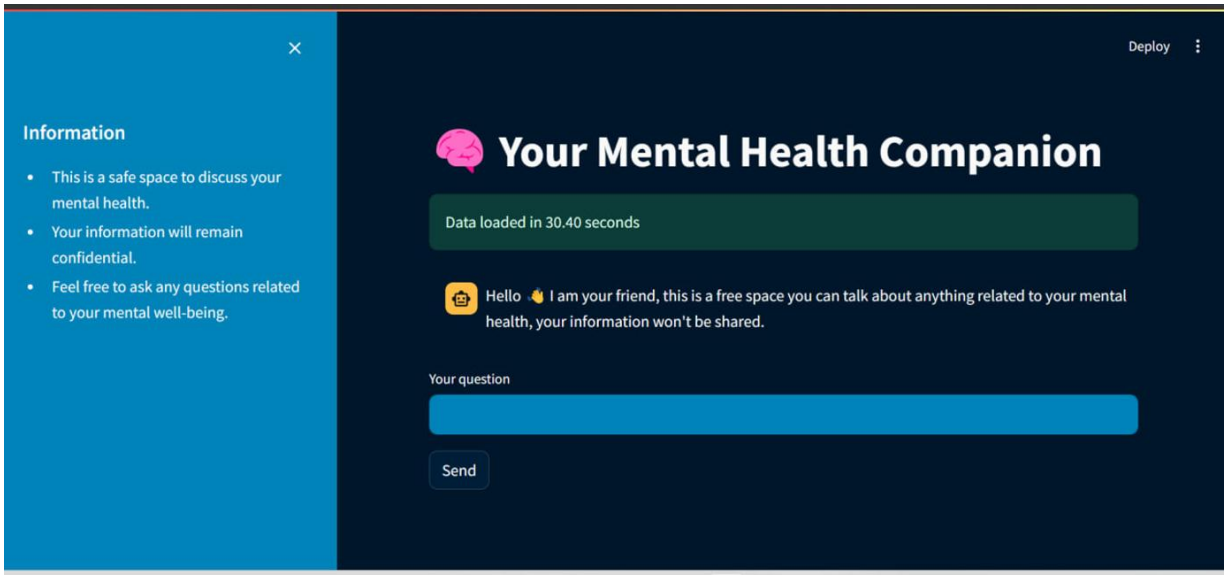
Deploy
Information
This is a safe space to discuss your mental health.
Your information will remain confidential.
Feel free to ask any questions related to your mental well-being.
Your Mental Health Companion
Data loaded in 30.40 seconds
Hello I am your friend, this is a free space you can talk about anything related to your mental health, your information won't be shared.
Your question
Send

Figure 3. Main page of the psychological support system web application

Table 1 presents examples of the interpretation of several user queries during the preliminary analysis stage. As shown in the examples, the message "*I have trouble sleeping at night. What can I do?*" demonstrates slightly positive polarity and moderate subjectivity. The message "*What if without it I can do something bad to myself?*" exhibits strongly negative polarity and a high degree of subjectivity, whereas the short message "*Are you sure?*" shows relatively positive polarity combined with a high level of subjectivity. The obtained polarity and subjectivity values are further used by the system as additional features for assessing the user's

psycho-emotional state and are incorporated into the query context during the recommendation generation process.

Figures 4 and 5 present examples of viewing dialogues stored in the cloud database of the Firebase platform. Figure 4 shows a fragment of a dialogue with an example of recommendations generated by the system for a user who requested support for anger management. Figure 5 presents an example of recommendations generated in response to a query related to coping with a depressed emotional state. These dialogues can be directly reviewed and analyzed by a professional psychologist in order to provide additional professional support to the client. In addition, the dialogue history is used by the system as context when generating responses to the current and subsequent user queries, taking into account the user's role in the system.

Table 1.

Examples of interpretation of user queries at the preprocessing and analysis stage

No.	User query	Polarity	Subjectivity
1	I have trouble sleeping at night. What can I do?	0.15	0.35
2	What if without it I can do something bad to myself?	-0.7	0.67
3	Are you sure?	0.5	0.89

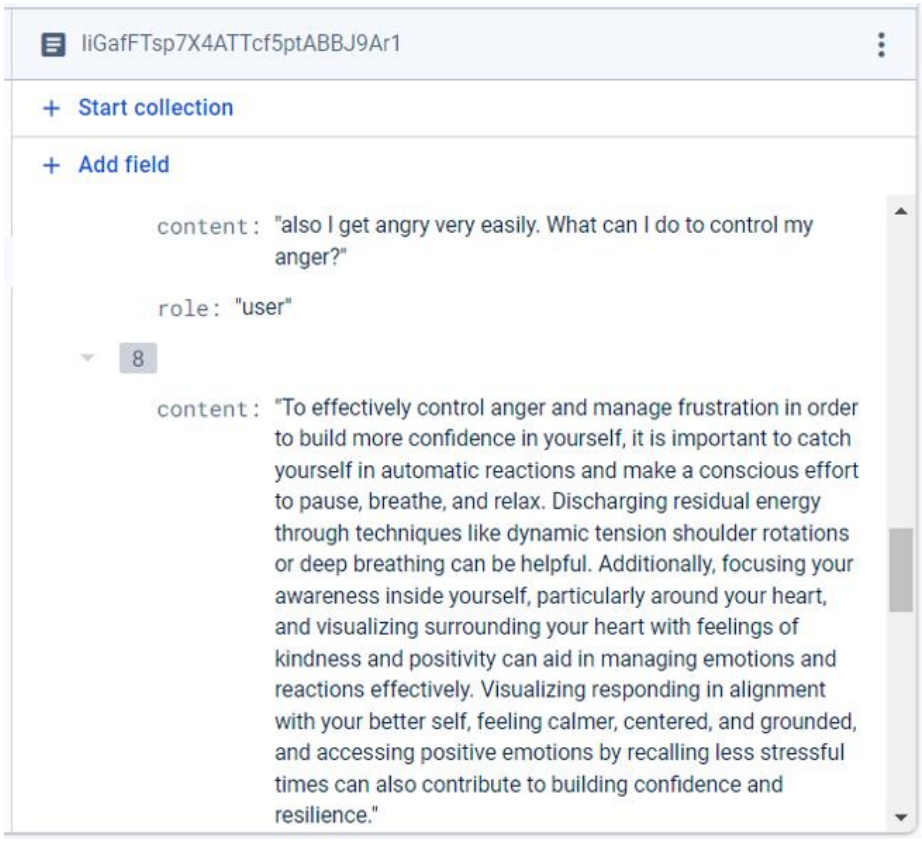
liGafFTsp7X4ATTcf5ptABBJ9Ar1
+ Start collection
+ Add field
content: "also I get angry very easily. What can I do to control my anger?"
role: "user"
8
content: "To effectively control anger and manage frustration in order to build more confidence in yourself, it is important to catch yourself in automatic reactions and make a conscious effort to pause, breathe, and relax. Discharging residual energy through techniques like dynamic tension shoulder rotations or deep breathing can be helpful. Additionally, focusing your awareness inside yourself, particularly around your heart, and visualizing surrounding your heart with feelings of kindness and positivity can aid in managing emotions and reactions effectively. Visualizing responding in alignment with your better self, feeling calmer, centered, and grounded, and accessing positive emotions by recalling less stressful times can also contribute to building confidence and resilience."

Figure 4. Example of generated recommendations for anger management

In cases where the analysis of the user's message indicates a potentially critical or unsafe psycho-emotional state, the system generates recommendations aimed at initial self-help and emotional stabilization, while strongly advising the user to seek assistance from a qualified specialist. An example of such a response is shown in figure 6.

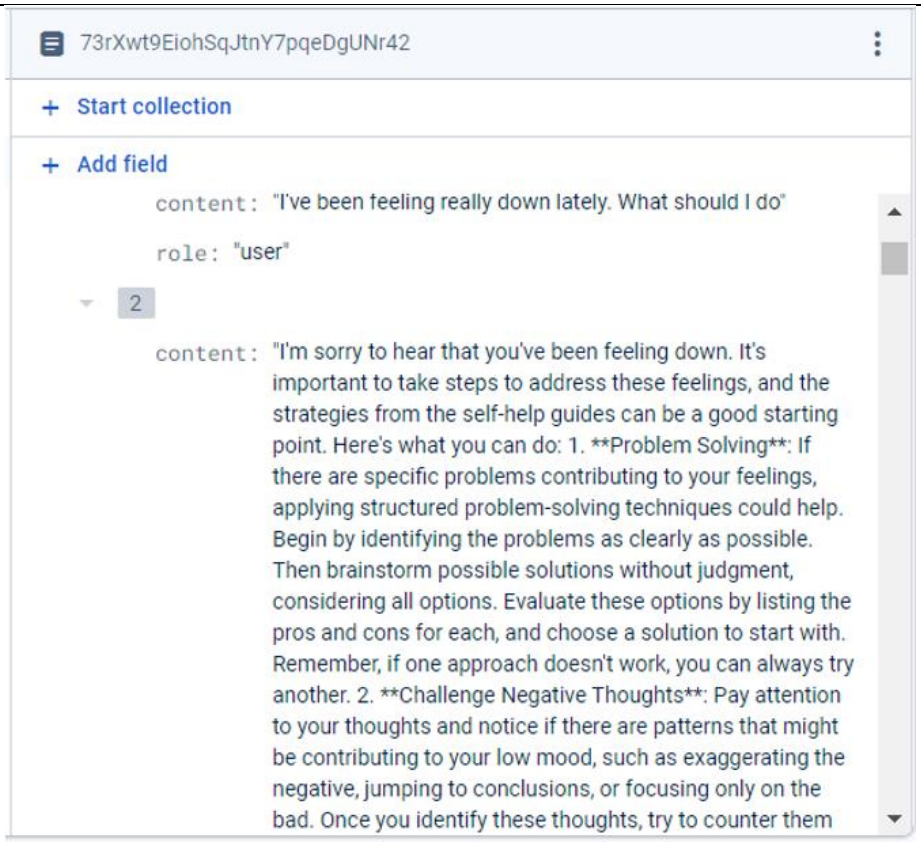
73rXwt9EiohSqJtnY7pqeDgUNr42
Start collection
Add field
content: "I've been feeling really down lately. What should I do"
role: "user"
2
content: "I'm sorry to hear that you've been feeling down. It's important to take steps to address these feelings, and the strategies from the self-help guides can be a good starting point. Here's what you can do: 1. **Problem Solving**: If there are specific problems contributing to your feelings, applying structured problem-solving techniques could help. Begin by identifying the problems as clearly as possible. Then brainstorm possible solutions without judgment, considering all options. Evaluate these options by listing the pros and cons for each, and choose a solution to start with. Remember, if one approach doesn't work, you can always try another. 2. **Challenge Negative Thoughts**: Pay attention to your thoughts and notice if there are patterns that might be contributing to your low mood, such as exaggerating the negative, jumping to conclusions, or focusing only on the bad. Once you identify these thoughts, try to counter them

Figure 5. Example of generated recommendations for coping with a depressed emotional state

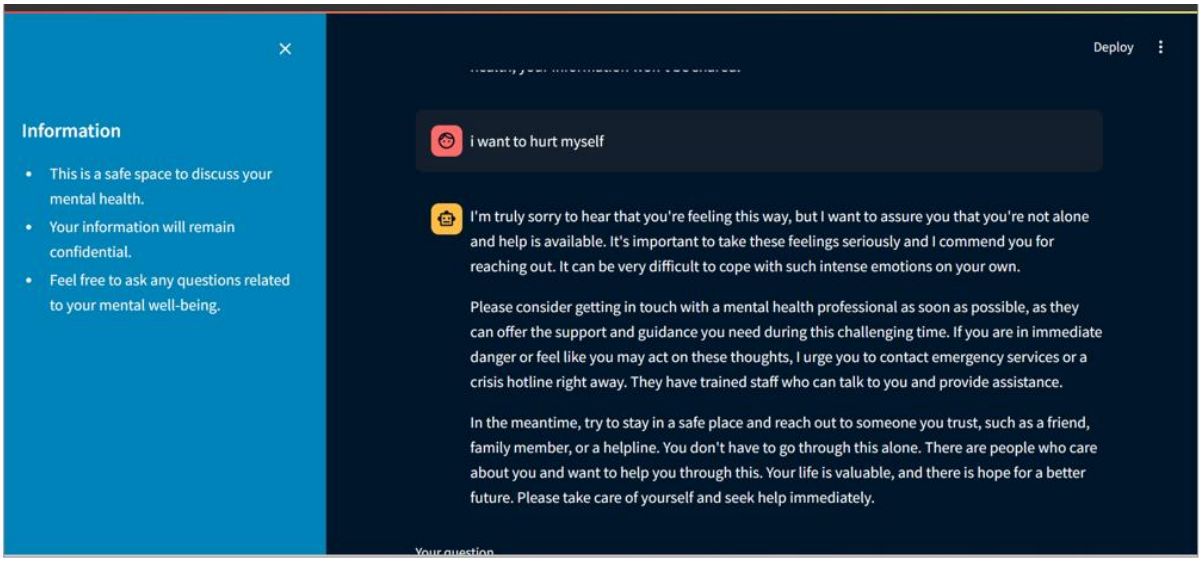
Information
This is a safe space to discuss your mental health.
Your information will remain confidential.
Feel free to ask any questions related to your mental well-being.
Deploy
i want to hurt myself
I'm truly sorry to hear that you're feeling this way, but I want to assure you that you're not alone and help is available. It's important to take these feelings seriously and I commend you for reaching out. It can be very difficult to cope with such intense emotions on your own.
Please consider getting in touch with a mental health professional as soon as possible, as they can offer the support and guidance you need during this challenging time. If you are in immediate danger or feel like you may act on these thoughts, I urge you to contact emergency services or a crisis hotline right away. They have trained staff who can talk to you and provide assistance.
In the meantime, try to stay in a safe place and reach out to someone you trust, such as a friend, family member, or a helpline. You don't have to go through this alone. There are people who care about you and want to help you through this. Your life is valuable, and there is hope for a better future. Please take care of yourself and seek help immediately.
Your question

Figure 6. Example of a response with self-help recommendations in a critical condition and a recommendation to contact a specialist

In the presented example, the system responds to the user query "*I want to hurt myself*" by generating a message expressing empathy and support. The system emphasizes that the person is not alone and that help is available. At the same time, it recommends contacting a professional psychologist or psychotherapist and, in situations where there is a risk to life, immediately reaching out to emergency services or crisis hotlines. The user is also advised to remain in a safe place and, if possible, avoid being alone.

The presented examples demonstrate that the system is capable of maintaining a dialogue with the user while generating responses based on the principles of empathetic communication, providing psychological support and offering recommendations aimed at stabilizing the user's emotional state.

Thus, the results of the prototype system implementation demonstrate its potential for use by individuals facing difficult life situations in the form of a virtual assistant for obtaining personalized self-help recommendations. For professional psychologists, the system can serve as a decision-support tool by automating the selection of relevant psychological techniques,

counseling scenarios, and support plans according to the specific situation of the client.

5. Experimental Studies and System Quality Evaluation

The prototype of the psychological support information system was validated through an experimental evaluation of information filtering quality using classical information retrieval metrics.

For the experimental evaluation, a set of test queries was formed to simulate typical scenarios of user requests in difficult life situations as well as professional queries from psychologists:

$$Q = \{q_1, q_2, \dots, q_N\}, \quad (7)$$

where Q denotes the set of test queries.

To construct the test queries and the corresponding reference relevant answers, expert psychologists were involved. In total $N = 75$ queries were generated and classified into thematic categories for patients and professional psychologists (tables 2 and 3). Such classification ensures a representative and balanced set of scenarios, enabling the evaluation of system performance in different contexts of psychological support.

For each query q_i, a set of relevant information objects from the professional knowledge repository was defined:

$$R(q_i) = \{i_1, i_2, \dots, i_m\}, \quad (8)$$

where $R(q_i)$ denotes the set of information objects $i \in I$ that are relevant for generating an appropriate psychological recommendation.

Table 2.

Categories of user queries

Category	Description	Number of queries
Stress and anxiety	Symptoms of stress, anxiety, and emotional exhaustion	10
Loss and life crises	Loss of loved ones, divorce, major life changes	8
Crisis psycho-emotional states	Suicidal thoughts, severe emotional destabilization	5
Interpersonal conflicts	Problems in family, workplace, friendships, bullying	8
Self-help and self-regulation	Requests for self-help and personal development recommendations	6
Psychological support in crisis situations related to war events	Psychological support for military personnel and civilians during shelling, air-raid alerts, loss of housing, property or relatives, after injury or captivity	8

Table 3.

Categories of professional psychologist queries

Category	Description	Number of queries
Selection of psychological methods	Choosing optimal psychological techniques for a specific client	8
Support planning	Development of psychological support plans	6
Structured counseling scenarios	Examples of structured counseling scenarios for working with a patient	5
Diagnostic approaches	Methods for diagnosing psycho-emotional states	5
Psychological support in crisis situations related to war events	Selection of methods and support plans for military personnel and civilians affected by combat, trauma, shelling, or losses	6

For each query q_i, the developed information system generated a list of information objects recommended for response generation:

$$S(q_i) = \{i_1, i_2, \dots, i_k\}, \quad (9)$$

where $S(q_i)$ represents a list of knowledge-base information objects ranked in descending order of relevance, and k is the fixed number of recommended objects used to ensure comparability of results.

To evaluate the quality of the developed prototype information system, classical metrics from information retrieval and recommender systems were used: Precision@k, Recall@k, and Mean Reciprocal Rank (MRR). These metrics allow a quantitative assessment of relevance, completeness, and ranking quality of the retrieved information objects. The metrics were calculated using the following formulas.

1. Precision@k evaluates filtering accuracy, i.e., the proportion of relevant results among the top k recommended objects:

$$Precision@k(q_i) = \frac{|S(q_i) \cap R(q_i)|}{k}. \quad (10)$$

This metric indicates how effectively the system avoids informational noise and prevents irrelevant recommendations, which is critically important in the psychological domain.

2. Recall@k measures the completeness of access to relevant knowledge (the proportion of relevant information objects retrieved):

$$Recall@k(q_i) = \frac{|S(q_i) \cap R(q_i)|}{|R(q_i)|}. \quad (11)$$

This metric characterizes the system's ability to identify relevant information objects without losing important knowledge, which is particularly important in decision-support systems for professional psychologists.

3. MRR evaluates the ranking quality of recommendations, defined as the average reciprocal rank of the first relevant result:

$$RR(q_i) = \frac{1}{rank_i}, \quad (12)$$

where $rank_i$ is the position of the first relevant information object in the list $S(q_i)$.

The average value of this metric is calculated as:

$$MRR = \frac{1}{N}\sum_{i=1}^{N} RR(q_i). \quad (13)$$

This metric is particularly important for dialog systems, as it reflects how quickly a user or a specialist receives a relevant recommendation.

Metric values were calculated for each query $q \in Q$ and averaged across the entire set of test queries:

$$Precision@k = \frac{1}{N}\sum_{i=1}^{N} Precision@k(q_i), \quad (14)$$

$$Recall@k = \frac{1}{N}\sum_{i=1}^{N} Recall@k(q_i). \quad (15)$$

In the experiments, $k = 5$ was used, which corresponds to a typical number of recommendations in decision-support systems.

To analyze the impact of the implemented recommendation generation approach, the metrics **Precision@k**, **Recall@k, and MRR** were calculated for three system configurations: without RAG (LLM without retrieval); RAG without contextual information; with contextual personalization. Table 4 presents the results obtained.

Table 4.

Quality evaluation of the psychological support information system

System configuration	Precision@5	Recall@5	MRR
Without RAG	0.65	0.52	0.68
RAG without contextual information	0.80	0.74	0.83
RAG with contextual personalization	0.88	0.83	0.91

The obtained results demonstrate a gradual improvement in recommendation quality with the introduction of the retrieval component and contextual adaptation. The metrics calculated without using RAG represent the baseline level of response generation based solely on the language models LLaMA/ChatGPT without access to the domain knowledge base. In this case, the relevance of recommendations is lower (Precision@5 ≈ 0.65).

In the second experiment, a significant improvement in recommendation quality was observed due to the use of the Retrieval Augmented Generation architecture (Precision@5 ≈ 0.80, Recall@5 ≈ 0.74). The third experiment, which incorporated contextual personalization, demonstrated the highest values of relevance, completeness, and ranking quality (Precision@5 ≈ 0.88, Recall@5 ≈ 0.83).

The experiments also revealed an improvement in the speed of obtaining relevant recommendations: the MRR value increased from approximately 0.68 to 0.91, indicating better ranking quality of the retrieved results. These findings confirm the effectiveness of the knowledge-based approach using semantic search, the Retrieval Augmented Generation architecture, and contextual personalization.

Thus, the results of the experimental studies confirmed the effectiveness of the proposed approach based on the use of generative artificial intelligence. Knowledge-based filtering with semantic and contextual adaptation within the Retrieval Augmented Generation architecture enables the generation of personalized, relevant, and timely recommendations tailored to the needs of different user categories, including psychological support scenarios in crisis situations related to war events. The system demonstrates the ability to adapt recommendations to the user's emotional state without relying on rigid rule-based mechanisms, which constitutes an important advantage for applications in the field of psychological support.

6. Conclusions

This paper proposes an approach to the development of an information system for psychological support that integrates the capabilities of generative artificial intelligence, semantic search, and knowledge-based information filtering. The system architecture implements the Retrieval Augmented Generation principle, enabling the combination of generative capabilities of large language models with semantic retrieval of relevant knowledge-base objects. Additionally, a mechanism for contextual adaptation has been implemented to generate personalized recommendations considering the user's role within the system (either a patient or a psychologist).

Experimental evaluation of the proposed approach using Precision@k, Recall@k, and Mean Reciprocal Rank (MRR) metrics demonstrated that the application of RAG architecture in combination with contextual personalization significantly improves the relevance of recommendations, coverage of knowledge, and ranking quality compared to an approach based solely on generative language models. The prototypical system was validated, confirming its potential use as an effective online psychological support service both for users experiencing challenging life situations and for psychologists in analyzing client inquiries and preparing recommendations.

Future research directions include expanding the system's domain-specific knowledge base, enhancing methods for contextual personalization of recommendations, and conducting larger-scale experimental studies involving a broader cohort of users and psychologists to comprehensively evaluate the practical effectiveness of the proposed system.

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